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10 × 4½
9 × 7
9 × 4
8 × 6
8 × 5
8 × 4
7 × 3¾
6 × 5
6 × 4½
6 × 3
5 × 4½
5 × 3
4 × 3
3 × 3
6 × 2
4¾ × 1¾
4 × 1¾
3 × 1½

,, 7 ,,
,, 5 ,,

	Weight per foot.
	about 95 lbs.
	,, 78 ,,
	,, 62 ,,
	,, 42 ,,
	,, 48 ,,
	,, 64 ,,
	,, 45 ,,
	,, 37 ,,
	,, 42 ,,
	,, 30 ,,
	,, 27½ ,,
	,, 24 ,,
	,, 21 ,,
	,, 52 ,,
	,, 30 ,,
	,, 27 ,,
	,, 19 ,,
	,, 17 ,,
	,, 24½ ,,
	,, 13½ ,,
	,, 19 ,,
	,, 11 ,,
	,, 10 ,,
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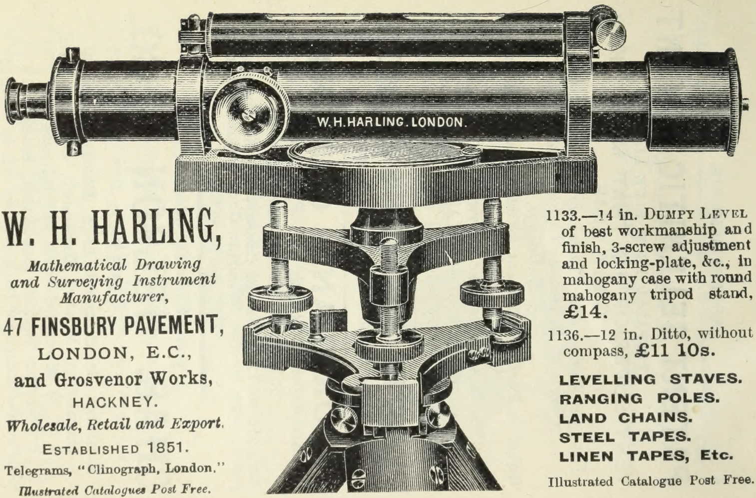
W. H. HARLING. LONDON.

[*Face Half-Title.*

HURST'S HANDBOOK

FOR ARCHITECTURAL SURVEYORS

A

HANDBOOK

OF

FORMULÆ, TABLES, AND MEMORANDA

FOR

Architectural Surveyors

AND OTHERS ENGAGED IN BUILDING

BY

JOHN THOMAS HURST

PAST PRESIDENT ASSOCIATION OF SURVEYORS
OF H.M. SERVICE.

FIFTEENTH EDITION

REVISED AND ENLARGED

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1905

PREFACE.

THE fact that fourteen editions of this work have been issued since 1864 shows that it has been of some service to the profession. During that period new light has been thrown on many subjects connected with Sanitary Engineering and the Construction of Buildings. The Author's experience has also increased with time, therefore the revision of the work became necessary.

The present edition (the 15th) is the result of the Author's practice extending over a period of more than forty years, most of which was in the service of the War Department, and embraced nearly every branch of the Engineers' and Surveyors' professions.

Some of the formulæ given in the work are original; most of them have been tested frequently in practice, and therefore may be relied upon.

It may, however, be necessary to inform the Student that very few of the formulæ in general use for such portions of the Art of Construction as Columns, Arches, &c., are based on a true theory. What is frequently given as such in

the ordinary text-books is very little more than mere hypothesis founded on imperfect data.

All knowledge being based on experience, science, that of building included, is nothing more than a systematic arrangement of facts and tracing their connection one with another, whereas hypothesis is merely the underlaying of the phenomena with such imaginary data as appear capable of accounting for the results.

Very few exhaustive experiments for the purpose of establishing a science of building have been made at any time. Most of those undertaken were limited to small and prepared specimens, nor has any systematic series of facts been recorded to help in forming a true theory of construction. The profession has, therefore, still to rely on formulæ mostly empirical, which have, to a limited extent, proved to be safe.

Euler's so-called theory of columns, from which most of the formulæ relating to that branch of construction have been derived, was based on the supposition that they yielded only by flexure. The theory of bridge arches assumes a structure consisting of voussoirs formed of a number of polished wedges, or of a mass of some material in which none of the principles of an arch could be traced. Neither of

these assumptions is likely to afford a theory of much value, hence the formulæ based on them cannot be very reliable.

Again, the Author has noticed in some of the commonly received text-books, when explaining to Students how the strength of roofs should be calculated, that undue importance is attached to the effects of wind, and very able methods have been proposed for determining the pressure exerted on the members of a truss by this, in some cases, imaginary force, whereas in practice the roofs of ordinary buildings are rarely, if ever, exposed to a crushing force from this cause, as the wind blown against the vertical walls modifies, in escaping upward, that against the sloping roof. Several other instances could be adduced where the Student without adequate experience is likely to be misled.

The Practical Engineer, Architect and Surveyor require formulæ that can readily be recalled to the mind, and which will indicate the law of the subject while they are marshalling the facts of their experience. Such formulæ must not be too involved or elaborate, otherwise they may lead to a mere mechanical process of manipulating figures.

LONDON: *July* 1, 1898.

HANDBOOK FOR SURVEYORS.

FORMULÆ USEFUL IN DESIGNING BUILDERS' WORK.

TENSILE STRENGTH.

TIE BARS, SUSPENSION RODS, &c.

W = Breaking weight in tons.
a = Area of section of bar in inches.
F = Tensile strength in tons per square inch.

$$W = F \times a.$$

VALUES OF F FOR IRON AND STEEL.

Description.	Breaking Weight per square inch. Highest.	Lowest.	Mean.	Ductility. Reduction of Original Area of Section at Fracture (Average).
	tons.	tons.	tons.	per cent.
Cast Iron, 2nd Melting, Bars 1 inch square	11	$4\frac{1}{2}$	$7\frac{3}{4}$	—
Ditto, ditto, Bars large ..	10	4	7	—
Wrought Iron, English Bars, Round or Square ..	30	18	24	25
Ditto ditto, Flat	28	17	$22\frac{1}{2}$	20
Ditto, ditto, Angle or Tee ..	28	16	22	15
Ditto, Plates with the Grain	27	16	$21\frac{1}{2}$	10
Ditto, ditto, across the Grain	26	14	20	5
Ditto, Wire, $\frac{1}{4}$-inch diameter and under	45	30	$37\frac{1}{2}$	25
Ditto, Hoop	24	18	21	—
Ditto, Swedish Bars	26	18	22	60
Steel Bars, Cast, as for tools	66	36	51	16
Ditto, Puddled	34	20	27	10
Steel Plates, Cast	44	30	37	18
Ditto, Puddled	46	26	33	6

VALUES OF F FOR VARIOUS MATERIALS.

Description.	Breaking Weight per square inch (Mean).
	tons.
Brass, Cast	8·00
" Wire	20·00
Copper, Cast	10·00
" Wrought	15·00
" Sheet..	13·00
" Wire..	25·00
" " annealed	14·00
Gun Metal (Copper, 8; Tin, 1)..	16·00
Lead, Cast	·75
" Milled or Rolled	1·25
Leather Bands for Machinery	1·30
Tin, English Block	2·00
Zinc, Sheet	5·25
Ash and Elm	2·00
Teak and Oak	3·00
Mahogany, Spanish	1·80
" Honduras	1·50
Northern Pine (*P. sylvestris*), Fir and Larch	1·50
Beech	1·90
Glass Tubes or Rods	1·20
Glue, solid	1·75
Glued Joint in Pine	·25
Plaster of Paris	·03
Portland Cement, Pure, after 7 days in water..	·11
Ditto, ditto, after 12 months in water ..	·19
Portland Cement and equal parts Sand, after 7 days in water	·04
Ditto, ditto, after 12 months in water ..	·12
Roman Cement, Pure, after 7 days in water..	·04
Ditto, ditto, after 12 months in water ..	·09
Slate	5·00

Materials of the quality ordinarily to be found in the market will seldom reach the mean strength given in the foregoing Tables.

The tensile strengths of timber given in the Table are those of clean specimens, free from knots and other defects.

In execution, the strength of timber used for ties will depend as much on the mode of forming the joints as on the scantling. If fixed at the ends by iron straps, or mortises and tenons, the resistance to shearing opposed to the bolts or pins may determine the strength.

In pine or fir the resistance to shearing, in the direction of the fibres, is about 500 lbs., and in oak 700 lbs. per square inch of the surface sheared.

The strength of iron tie bars, bridge links, &c., depends partly on the mode of forming the connections. If the bearing area of rivets, the quantity of metal around a bolt hole or eye of a connection be insufficient, the welding imperfect, or the iron burned in forging, the strength due to the body of the bar will not be obtained.

In suspension links of flat bar iron, it is found that the sum of the widths of the metal around the sides of the bolt hole should be about a $\frac{1}{4}$th in excess of that of the body of the link, and the metal around the top should be $\frac{7}{8}$ths of the width of the body of the link. The pin should be in diameter at least $\frac{2}{3}$rds of the width of the body of the link.

The Extension for each ton of direct strain per square inch within the elastic limit of the material is usually assumed, for

Cast iron at			$\frac{1}{5500}$
Wrought iron at	$\frac{8}{100000}$	to	$\frac{1}{10000}$
Steel bars	,, $\frac{1}{10000}$	,,	$\frac{1}{15000}$

These are only approximations, for Kirkaldy has

shown that the elasticity of iron and steel varies in different samples.

Fibrous iron elongates considerably under excessive strains, and when it breaks the fractured part is much reduced in section. Iron of inferior quality being scarcely reduced at all.

Iron in tie bars, straps, &c., should be tough and fibrous, or it would be liable to snap under the sudden application of a stress that otherwise would be within its strength

Annealing wrought iron reduces its tensile strength, but increases its ductility.

Iron is injured by being brought to a white or welding heat if not at the same time hammered or rolled.

Steel when tempered in oil is both harder and tougher than when tempered in water.

A tie bar to resist with safety the sudden application of a given stress requires to have twice the strength that is necessary to resist the gradual application and steady action of the same stress.

CHAINS.

To find the breaking weight in tons.

Divide the square of the diameter of one bar of the link in 16ths of an inch by 10 for short and long linked chains, and by 11 for studded chains.

The Admiralty proof per circular $\frac{1}{8}$th of an inch is for open or long-linked 315 lbs., for close or short-linked chains 420 lbs., and for studded chains 630 lbs. The studded chains being stiffer, although of less ultimate strength, admit of a higher proof stress than either close or open linked chain.

Long-link chains without studs are chiefly used for ships' moorings and buoys, stud-link chains for cables, and short or close link chains for cranes and similar purposes.

The following Table is calculated by the foregoing Rules, which give $16\frac{1}{4}$ tons nearly per square inch as the breaking weight of each bar in short-linked chains, and 15 tons nearly in studded chains. The bar iron in both cases being taken at a breaking strength of 24 tons per square inch.

The Strength of Iron Chain.

Short Linked.			Cable—Studded.		
Diameter of Link.	Admiralty Proof.	Breaking Weight.	Diameter of Link.	Admiralty Proof.	Breaking Weight.
inches.	tons.	tons.	inches.	tons.	tons.
$\frac{3}{16}$	$\frac{2}{5}$	·9	$\frac{1}{2}$	$4\frac{1}{2}$	5·8
$\frac{1}{4}$	$\frac{3}{4}$	1·6	$\frac{9}{16}$	$5\frac{1}{2}$	7·4
$\frac{5}{16}$	$1\frac{1}{8}$	2·5	$\frac{5}{8}$	7	9·1
$\frac{3}{8}$	$1\frac{5}{8}$	3·6	$\frac{11}{16}$	$8\frac{1}{2}$	11·0
$\frac{7}{16}$	$2\frac{1}{4}$	4·9	$\frac{3}{4}$	$10\frac{1}{8}$	12·2
$\frac{1}{2}$	3	6·4	$\frac{7}{8}$	$13\frac{3}{4}$	17·8
$\frac{9}{16}$	$3\frac{1}{4}$	8·1	1	18	23·3
$\frac{5}{8}$	$4\frac{3}{8}$	10·0	$1\frac{1}{8}$	$22\frac{3}{4}$	29·5
$\frac{11}{16}$	$5\frac{3}{8}$	12·1	$1\frac{1}{4}$	$28\frac{1}{8}$	36·4
$\frac{3}{4}$	$6\frac{3}{4}$	14·4	$1\frac{3}{8}$	34	44·0
$\frac{13}{16}$	$7\frac{7}{8}$	16·9	$1\frac{1}{2}$	$40\frac{1}{2}$	52·4
$\frac{7}{8}$	$9\frac{1}{8}$	19·6	$1\frac{5}{8}$	$47\frac{1}{2}$	61·5
$\frac{15}{16}$	$10\frac{1}{2}$	22·5	$1\frac{3}{4}$	$55\frac{1}{8}$	71·3
1	12	25·6	$1\frac{7}{8}$	$63\frac{1}{4}$	81·8
$1\frac{1}{8}$	$15\frac{1}{4}$	32·4	2	72	93·1
$1\frac{1}{4}$	$18\frac{3}{4}$	40·0	$2\frac{1}{8}$	$81\frac{1}{4}$	105·1
$1\frac{3}{8}$	$22\frac{5}{8}$	48·4	$2\frac{1}{4}$	$91\frac{1}{8}$	117·8
$1\frac{1}{2}$	27	57·6	$2\frac{3}{8}$	$101\frac{1}{2}$	122·2
$1\frac{5}{8}$	$31\frac{5}{8}$	67·6	$2\frac{1}{2}$	$112\frac{1}{2}$	145·5
$1\frac{3}{4}$	$36\frac{3}{4}$	78·4	$2\frac{3}{4}$	$136\frac{1}{8}$	176·0

The working load of chains should not exceed $\frac{1}{6}$th of the breaking weight.

ROPES.

The circumference in inches being represented by C, the breaking weight in tons will be, for

Hemp hawser laid = $\cdot 20C^2$.	Iron wire = $1\cdot 40C^2$.
„ shroud laid = $\cdot 28C^2$.	Steel „ = $2\cdot 50C^2$.

The breaking weight per square inch of flat ropes of hemp, iron, or steel appears to vary with the thickness, the thinest being usually the strongest.

The hemp ropes in the above rules are supposed to be four-strand tarred Russian hemp. Untarred white ropes are about 5 per cent. stronger.

Three-stranded ropes are *one-fifth* stronger than four-stranded.

A splice weakens a rope about *one-eighth.*

Manilla hemp is much stronger and more to be depended upon than Russian, as the latter is injured by the process of rotting practised in Russia.

A good hemp rope is more to be depended upon for lifting heavy weights than an iron chain, as the latter is liable to snap on surging.

Hemp ropes lose strength by wear. Those from four to six months in constant use are often weaker than new by one-fourth. Russian hemp also loses by immersion in water.

When ropes and chains are strained, as in the act of hauling, the tension arising from their own weight is greatly increased. Therefore add to the weight to be moved that of the rope or chain multiplied by the number opposite to the ratio of deflection from a straight line, as given in the following Table :—

Ratio of deflection	$\frac{1}{40}$	$\frac{1}{20}$	$\frac{1}{15}$	$\frac{1}{14}$	$\frac{1}{13}$	$\frac{1}{12}$	$\frac{1}{11}$	$\frac{1}{10}$
Multiplier	5·200	2·536	1·943	1·823	1·700	1·572	1·460	1·340

THE STRENGTH OF ROPES.

Hemp.			Iron Wire.		Steel Wire.	
	Hawser.	Shroud.				
Girth.	Breaking Weight.	Breaking Weight.	Girth.	Breaking Weight.	Girth.	Breaking Weight.
inches.	tons.	tons.	in.	tons.	in.	tons.
¾	·11	·16	¾	·79	¾	1·41
1	·20	·28	1	1·40	1	2·50
1½	·45	·63	1¼	2·19	1⅛	3·16
2	·80	1·12	1½	3·15	1¼	3·90
2½	1·25	1·75	1¾	4·29	1⅜	4·73
2¾	1·51	2·12	2	5·60	1½	5·62
3	1·80	2·52	2⅛	6·32	1⅝	6·60
3½	2·45	3·43	2¼	7·09	1¾	7·66
4	3·20	4·48	2⅜	7·90	1⅞	8·79
4½	4·05	5·67	2½	8·75	2	10·00
5	5·00	7·00	2⅝	9·65	2⅛	11·29
5½	6·05	8·47	2¾	10·59	2¼	12·66
6	7·20	10·08	3	12·60	2⅜	14·10
6½	8·45	11·83	3⅛	13·67	2½	15·62
7	9·80	13·72	3¼	14·79	2⅝	17·23
7½	11·25	15·75	3⅜	15·95	2¾	18·91
8	12·80	17·92	3½	17·15	2⅞	20·66
8½	14·45	20·23	3⅝	18·40	3	22·50
9	16·20	22·68	3¾	19·69	3⅛	24·41
9½	18·05	25·27	4	22·40	3⅜	28·48
10	20·00	28·00	4½	28·35	3½	30·62
10½	22·05	30·87	5	35·00	3⅝	32·85
11	24·20	33·88	5½	42·35	3¾	35·16
12	28·80	40·32	6	50·40	4	40·00

The working load should not exceed $\frac{1}{6}$th of the breaking weight.

TABLE OF CHAINS, HEMP, AND IRON-WIRE ROPES, CONSIDERED TO BE OF EQUAL STRENGTH.

Hemp, cir.	3″	4″	5″	6″	7″	8″	9″	10″
Wire, ,, ...	1¼	1¾	2	2½	3	3½	3¾	4¼
Chain, diam. ...	$\frac{5}{16}$	⅜	½	⅝	¾	⅞	1	1⅛

THE STRENGTH OF FLAT ROPES.

(NEWALL AND CO.)

Hemp.	Iron Wire.	Steel Wire.	Equivalent Breaking Weight in Tons.
Size in inches.	Size in inches.	Size in inches.	
$4 \times 1\frac{1}{8}$	$2\frac{1}{4} \times \frac{1}{2}$	—	20
$5 \times 1\frac{1}{4}$	$2\frac{1}{2} \times \frac{1}{2}$	—	23
$5\frac{1}{2} \times 1\frac{3}{8}$	$2\frac{3}{4} \times \frac{5}{8}$	—	27
$5\frac{3}{4} \times 1\frac{1}{2}$	$3 \times \frac{5}{8}$	$2 \times \frac{1}{2}$	28
$6 \times 1\frac{1}{2}$	$3\frac{1}{4} \times \frac{5}{8}$	$2\frac{1}{4} \times \frac{1}{2}$	32
$7 \times 1\frac{7}{8}$	$3\frac{1}{2} \times \frac{5}{8}$	—	36
$8\frac{1}{4} \times 2\frac{1}{8}$	$3\frac{3}{4} \times \frac{11}{16}$	$2\frac{1}{2} \times \frac{1}{2}$	40
$8\frac{1}{2} \times 2\frac{1}{4}$	$4 \times \frac{11}{16}$	$2\frac{3}{4} \times \frac{3}{8}$	45
$9 \times 2\frac{1}{2}$	$4\frac{1}{4} \times \frac{3}{4}$	$3 \times \frac{3}{8}$	50
$9\frac{1}{2} \times 2\frac{3}{8}$	$4\frac{1}{2} \times \frac{3}{4}$	$3\frac{1}{4} \times \frac{3}{8}$	56
$10 \times 2\frac{1}{2}$	$4\frac{5}{8} \times \frac{3}{4}$	$3\frac{1}{2} \times \frac{3}{8}$	60

The working load, according to the makers' Table, should not exceed $\frac{1}{10}$th of the breaking weight.

COMPARATIVE TENSILE STRENGTH OF WIRE.

Iron wire, annealed	= 1·000
,, hard	= 1·491
Steel, annealed	= 1·289
,, hard	= 2·849
Copper, annealed	= 0·913
,, hard	= 1·400
Brass, annealed	= 1·143
,, hard	= 1·711

The Strength of Iron Wire.

S.W.G.	Diam. in inches.	Ultimate Tensile Strength in lbs.		S.W.G.	Diam. in inches.	Ultimate Tensile Strength in lbs.	
		Soft.	Hard.			Soft.	Hard.
7/0	·500	9817	14,726	13	·092	332	499
6/0	·464	8455	12,682	14	·080	251	377
5/0	·432	7329	10,993	15	·072	204	305
4/0	·400	6283	9,425	16	·064	195	292
3/0	·372	5434	8,151	17	·056	123	185
2/0	·348	4756	7,134	18	·048	90	136
0	·324	4122	6,184	19	·040	63	94
1	·300	3534	5,301	20	·036	51	76
2	·276	2991	4,487	21	·032	40	60
3	·252	2494	3,741	22	·028	31	46
4	·232	2114	3,171	23	·024	23	34
5	·212	1765	2,647	24	·022	19	29
6	·192	1448	2,171	25	·020	16	24
7	·176	1216	1,825	26	·018	13	19
8	·160	1005	1,508	27	·0164	11	16
9	·144	814	1,221	28	·0148	9	13
10	·128	643	965	29	·0136	7	11
11	·116	528	793	30	·0124	6	9
12	·104	425	637				

Tests for Wrought Iron (Kirkaldy).

Description.	Superior English Iron.		Medium English Iron.		Ordinary English Iron.	
	Tensile Strength.	Area of Fracture.	Tensile Strength.	Area of Fracture.	Tensile Strength.	Area of Fracture.
	tons.	per cent.	tons.	per cent.	tons.	per cent.
Bars, round or square	27	45	25	30	23	20
„ flat	26	40	24	25	22	16
Angle or T	25	30	23	18	21	12
Plates, lengthway ..	24	20	22	12	20	8
„ crossway ..	22	12	19	7	17	3

TRANSVERSE STRENGTH.

ELEMENTARY PRINCIPLES.

The strength of a beam to resist cross breaking is determined by the relation of the moment or *leverage* M_l of the load to the moment or *leverage* M_r of the forces due to the resistance of the material. So that

$$M_l = M_r.$$

The other forces which affect the strength of a beam are those which cause it to shear both horizontally and vertically. The consideration of these, however, in solid beams and the small girders used by the architect and builder, owing to the excess of material in the parts affected, may usually be neglected.

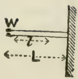
Moments of the Load.

L = Length of the beam.
l = Distance of load from any cross section.
m and n = Length of the parts into which a beam is divided by an intermediate load.
W = Load.

Note.—So long as the same terms are used throughout, it does not matter whether L, l, &c., be taken to represent inches or feet, or W to represent lbs., cwts., or tons, the results will be in the terms adopted.

Beam fixed at one end.

$$M_l = Wl.$$



The moment of a load is a maximum

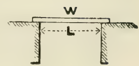
when $$M_l = WL.$$

A load uniformly distributed over the length has a moment = one-half of that of a load concentrated at the extremity.

When a load is partially or irregularly distributed, the moment about any given point will be the sum of the moments of each weight or particle of the load taken separately.

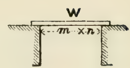
Beams supported at both ends.

When the load is on the middle, the moment about the same point is



$$M_1 = \frac{W L}{4}$$

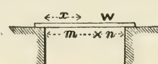
And when the load is at any other point, the moment at that point is



$$M_1 = \frac{W m n}{L}$$

In all cases, the greatest moment will be at the point of application of the load, from whence it diminishes until it becomes nothing at the supports.

When the moment is required at any other point than that where the load is applied, let x = the distance of that point from the adjoining pier, m being taken as the length of the segment between the load and the pier from which x is measured, then



$$M_1 = \frac{W n x}{L}$$

When the load is uniformly distributed over the length,

$$M_1 = \frac{W L}{8}.$$

When the beam is loaded in the middle, and also with a uniformly distributed load, the moment about a point at the middle will be the sum of the moments of the central and distributed load.

When a beam is loaded at several points, the moment at any point due to the weights equals the sum of the moments about that point taken separately.

NOTE.—The moment of any load divided by the depth of the beam will give the horizontal strain on the extreme fibres in its upper and lower sides.

MOMENT OF RESISTANCE.

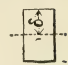
A loaded beam resists fracture by the strength of its fibres. In a cross section taken at right angles to the axis of the beam, two portions will be found strained in opposite directions, one in compression and the other in tension; the line separating the two is called the *neutral axis*, which, in a perfectly elastic material, is supposed to pass through the centre of gravity of the section.

The fibres in each portion of the cross section are not all strained alike, those farthest from the neutral axis undergoing the greatest strain. The resistance offered by the fibres is usually assumed to be in proportion to their area, amount of extension, and distance from the neutral axis; or, as the amount of extension is also in proportion to the distance from

the neutral axis, the resistance of the fibres will be in proportion simply to their areas, multiplied by the *squares* of their respective distances from the neutral axis. The sum of these results calculated for the whole section is equal to the *moment of inertia* of that section, usually denoted by the letter I.

If the tensile stress of which the material is capable, say in tons, cwts., or lbs., per square inch, be divided by the distance of the extreme fibres from the neutral axis on the stretched side of the section, and the compressive stress by the distance of the extreme fibres from the neutral axis on the compressed side of the section, and the lesser of these quotients be multiplied by the moment of inertia of the section, the product will be the moment of resistance = M_r.

Therefore, if F be taken to represent the tensile or compressive stress per unit of area (usually in lbs. or tons per square inch), as deduced from experiment on transverse beams, and δ the distance of the extreme fibres from the neutral axis, as sketch, then



$$M_r = \frac{F\,I}{\delta}$$

The value of F will vary according to the distribution of the material in the cross section of the beam. If the whole of it were assumed to be concentrated in the upper and lower edges at the distance δ from the neutral axis, then F would equal the strength of the material per square inch due to direct tension or crushing; in all other cases the value of F will exceed these quantities, varying approximately in the ratio of the thickness of the intermediate part of the section or web to the width of the flange.

To find the moment of inertia:—

The value of I may be found approximately for any section by drawing a line through its centre of

gravity to represent the neutral axis, and by dividing the section into narrow strips parallel to it, and multiplying the area of each by the square of its mean distance from the same axis. The sum of all the products will nearly equal the moment of inertia. The greater the number of the strips the nearer will be the result to the true value.

The following are the correct values of I for some of the sections used in practice:—

	Values of I.
Square or rectangle strained in the direction of a side	$= \frac{b\,d^3}{12}$
Square strained in the direction of its diagonal	$= \frac{D^4}{48}$
Hollow rectangle, or square ..	$= \frac{b\,d^3 - b'\,d'^3}{12}$
Ditto, strained in the direction of its diagonal	$= \frac{D^4 - D'^4}{48}$
Circle	$= \cdot 7854\ R^4$
Hollow circle	$= \cdot 7854\ R^4 - r^4$
Semicircle, from centre of gravity	$= \cdot 11\ R^4$
Triangle, ditto	$= \frac{b\,d^3}{36}$

b, d, D, and R being the breadth, depth, diagonal, and

radius respectively, b', d', D′, and r representing the corresponding dimensions of the interior of hollow sections.

Application of the foregoing to the strength of beams.

If the values of the moment of the load and the resistance of the beam be equated, formulæ will be obtained for determining the transverse strength of a beam of any section to resist fracture. Thus, for a beam supported at the ends and loaded in the middle,

$$M_l = \frac{W\,L}{4} \text{ (p. 11), and } M_r = \frac{F\,I}{\delta} \text{ (p. 13);}$$

therefore

$$\frac{W\,L}{4} = \frac{F\,I}{\delta}$$

Or,

$$W = \frac{4\,F\,I}{L\,\delta}$$

or for a rectangular section (see p. 14), making $d = 2\,\delta$,

$$W = \frac{4\,F\,b\,d^2}{6\,l}$$

b, d, and l being in the same terms.

NOTE.—Owing to the fact that these formulæ require a separate constant for each form of section, they are used by practical engineers in those cases only where no experiments have been made on cross breaking, as they are supposed to enable the strength to be derived from experiments on direct tension and compression, but which often lead to very erroneous results.

These general formulæ are usually simplified in their application to special cases as follows :—

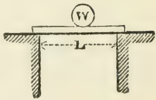
RULES FOR PRACTICE.

STRENGTH.

Beams, cross section rectangular, supported at both ends.

$$\left.\begin{array}{l} b = \text{Breadth} \\ d = \text{Depth} \end{array}\right\} \text{in inches.}$$

L = Length in feet.
W = Breaking weight in cwts.



Load in the middle,

$$W = C \frac{b\, d^2}{L}$$

C being the weight in cwts. required to fracture a bar 1 inch square and 1 foot long.

C = 35·0 rolled steel.
22·0 wrought iron.
18·0 cast iron, small bars.
16·0 „ large „
10·0 brass.
6·0 ash, English.
5·0 „ American.
3·0 „ „ black.
4·5 beech.
4·0 birch, American, black.
5·0 blue gum, Australian.
3·5 cedar (*C. odorata*), West Indies.
4·6 deodar, Indian.
3·0 elm, English.
5·5 „ rock, Canadian.

Value of C—*continued.*

C = 3·6 fir, white spruce (*A. excelsa*).
8·0 greenheart, Demerara.
3 5 hemlock, American,
6·0 hickory, American.
4·5 Jarrah, Australian.
4·8 Kauri pine, New Zealand.
3·5 larch, English.
4·9 mahogany, Honduras.
5·0 „ Cuban.
5·0 mango, India.
4·7 maple, black, American.
7·0 mora, Demerara.
5·0 oak, English.
5·2 „ American, white.
4·3 „ Baltic.
4·0 pine, Northern, Dantzic and Memel.
3·5 „ „ Riga.
5·0 „ pitch, American.
4·0 „ red „
3·8 „ white „ (*P. strobus*).
5·0 poon, India.
4·8 poplar, English, white.
7·5 sâl, India.
6·0 sissoo „
4·0 stringy bark, Australia.
3·5 tamarak, America.
5·0 teak, Burmah.
5·4 toon, India.
2·5 slate, Welsh.

Note.—For wood, as the experiments were made on small and selected specimens, a reduction of ¼ to ½ should be made from the above values of C in large and unselected beams.

When the diagonal of a square beam is vertical, its strength, according to theory, is to the same beam when the side is vertical, as 1 to the $\sqrt{2}$ or as 5 to 7 nearly.

Hollow Rectangular Beams, supported at both ends and loaded on the middle :

$$W = C\,\frac{b\,d^3 - b'\,d'^3}{L\,d}$$

b' and d' being the internal dimensions.

Cylindrical Beams supported and loaded as last.

$$W = \frac{10}{17} \times \frac{C\,d^3}{L}$$

Hollow Cylindrical Beams.

$$W = \frac{0}{17} \times C\,\frac{d^4 - d'^4}{L\,d}$$

d being the external and d' the internal diameters of the beam in inches.

NOTE.—The formula for hollow beams can only be taken as a rough approximation to the correct strength, and requires the constant C to be found by experiment in each case.

The factor of safety to be adopted for wood beams is $\frac{W}{5}$ for a stationary load, and $\frac{W}{7}$ for a moving load. Greater permanent loads injure the elasticity of the wood, and cause the beam in the course of time to bend, by producing a permanent set in the fibres.

The maximum strength of a wood beam is attained when the breadth is to the depth as 5 to 7, or when it is strutted to prevent lateral movement, otherwise the calculated strength will be in excess.

Breaking Weight according to Position of Load and Mode of Fixing, &c.

Applicable to all Beams and Girders.

Beams supported at both ends and loaded on the middle .. .. .. $= W$

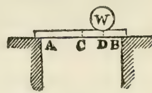
Ditto supported at one end, and fixed at the other, the load on the middle $= W \times 1\frac{3}{4}$

Ditto fixed at both ends and loaded on the middle .. .. $= W \times 1\frac{1}{2}$

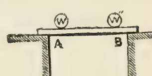
Ditto fixed at one end ..  $= \frac{W}{4}$

Beams in all cases will support double the load when distributed over the length that they would if placed on the middle.

If the load be applied at any other point, as at D, the breaking weight at that point will equal the square of half the length A B, multiplied by the breaking weight if the load were on the middle, and divided by the product of the distance A D and D B from the ends.



If equal loads W′ and W″ be applied at any two points equidistant from the middle, the breaking weight at each of the points will equal that if applied at the middle, multiplied by the *length* of the beam A B, and divided by *twice* the difference between that length and the distance apart of the two weights.



E. g. a beam loaded at two points $\frac{1}{4}$th of the length

from each end will sustain double the load that it would in the middle.

NOTE.—Other cases can readily be solved by the formulæ for the moments of the load (p. 10).

When a beam is continued over three or more points, and the load is *uniformly* distributed, it will be sufficient to treat each of the intermediate spans as a beam *fixed at both ends*, and the two outer ones each as a beam supported at one end and fixed at the other. To support a uniform load when the cross section of the beam is uniform, the length of the outer bays should not much exceed $\frac{3}{4}$ths of the intermediate ones.

If some of the bays have a greater load than the others, it will be sufficiently near in practice to take the parts so loaded as *supported* at the ends only.

In the case of a beam uniformly loaded and supported at several equidistant points, the portion of the load bearing on each support is as follows:

Let W = the load between each pair of supports.

No. of Supports.	Number of each Support.									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
	Parts of the Load W.									
2	$\frac{1}{2}$	$\frac{1}{2}$								
3	$\frac{3}{8}$	$\frac{10}{8}$	$\frac{3}{8}$							
4	$\frac{4}{10}$	$\frac{11}{10}$	$\frac{11}{10}$	$\frac{4}{10}$						
5	$\frac{11}{28}$	$\frac{32}{28}$	$\frac{26}{28}$	$\frac{32}{28}$	$\frac{11}{28}$					
6	$\frac{15}{38}$	$\frac{43}{38}$	$\frac{37}{38}$	$\frac{37}{38}$	$\frac{43}{38}$	$\frac{15}{38}$				
7	$\frac{41}{104}$	$\frac{118}{104}$	$\frac{108}{104}$	$\frac{106}{104}$	$\frac{108}{104}$	$\frac{118}{104}$	$\frac{41}{104}$			
8	$\frac{56}{142}$	$\frac{161}{142}$	$\frac{137}{142}$	$\frac{143}{142}$	$\frac{143}{142}$	$\frac{137}{142}$	$\frac{161}{142}$	$\frac{56}{142}$		
9	$\frac{152}{388}$	$\frac{440}{388}$	$\frac{374}{388}$	$\frac{392}{388}$	$\frac{386}{388}$	$\frac{392}{388}$	$\frac{374}{388}$	$\frac{440}{388}$	$\frac{152}{388}$	
10	$\frac{209}{530}$	$\frac{601}{530}$	$\frac{511}{530}$	$\frac{535}{530}$	$\frac{529}{530}$	$\frac{529}{530}$	$\frac{535}{530}$	$\frac{511}{530}$	$\frac{601}{530}$	$\frac{209}{530}$

NOTE.—If the beams were *perfectly* rigid, all the supports except the end ones would sustain W, and the end ones would each sustain $\frac{1}{2}$ W.

The distance from the pier of the point of contra-flexure in a beam of uniform section fixed at one end and supported at the other

When loaded in the middle is ·273 L.

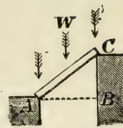
Ditto when uniformly loaded ·267 L.

Ditto if fixed at both ends and loaded in the middle = ·25 L.

Ditto, ditto, when uniformly loaded ·211 L.

L being the distance between the piers.

Inclined Beams.

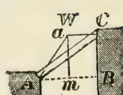


Supported at the ends have their breaking weights equal to those of the same beams placed horizontally. When multiplied by the length A C and divided by the horizontal distance or span A B.

The *vertical pressures* on the supports due to a uniformly distributed or central load are—

$$\text{On A} = W \frac{AC}{AB + AC}$$

$$\text{,, C} = W \frac{AB}{AB + AC}$$



The *horizontal thrust* = H against the supports A and C when the vertical line $a\ m$ passes through the centre of gravity of the load is

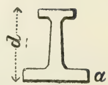
$$H = \frac{W \times Am}{CB}$$

When W is either uniformly distributed or concentrated in the centre, then—

$$H = \frac{W \times A\,B}{2\,C\,B}$$

The *resultant* of the vertical and horizontal forces on the pier A is in the direction and equals the length of the line a A when $a\,m$ represents the load.

Cast-iron Flanged Girders.



a = Area of bottom flange in inches.
d = Depth of girder in inches.
L = Length of bearing in feet.
W = Breaking weight in tons on the middle.

$$W = 2\,\frac{a\,d}{L}$$

The sectional area of the top flange should not be less than $\frac{1}{6}$th of the area of the bottom flange, this being the proportion when both flanges are on the point of yielding under the load as ascertained by experiment. To prevent the upper flange from yielding first, its area should be increased to $\frac{1}{4 \cdot 5}$th of the bottom flange, this being the best proportion for stiffness if the load rests on the top, or on both sides of the bottom flange; if it rests on one side only, the proportion should be $\frac{1}{3}$rd.

The *web* at the top and bottom is usually made the same thickness as the flange which it adjoins. Stiffening pieces, called "feathers," should be cast on the sides of the web as a precaution against lateral flexure. They must not, however, extend entirely up to the top flange, as they would then be liable to fracture in cooling.

The outline of the top of the girder may be in the form of an elliptic curve, but the depth at the ends should not be less than $\frac{1}{2}$ that at the centre. If the top and bottom flanges are horizontal, the width of the bottom flange may be reduced from the centre to the ends in the form of a parabolic curve.

Girders of cast iron should seldom be used for greater spans than about 25 feet, and the depth should never be less than $\frac{1}{20}$th of the span.

Cast iron being a material of uncertain strength, both as regards the quality of the iron and the risk of flaws in casting, a larger factor of safety is required than for wrought iron; therefore take

$\frac{W}{5}$ when the load is stationary.

$\frac{W}{8}$ when the load is moving.

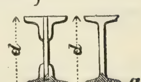
$\frac{W}{3}$ proof load, which should not be exceeded.

Wrought-iron Flange and Box Girders.

Supported at both ends.

a = Area of tension or bottom flange (the part shaded in sketch) } in inches.

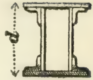
d = Depth in inches.
L = Length in feet.
W = Breaking weight in tons.



Load on the middle.

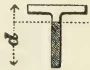
$$W = C\frac{a\,d}{L}$$

C = 6·0 for plate girders.	C = 3·2 for ⊥ girders.
6·5 „ box „	3·5 „ ┌ „
6·5 „ rolled „	2·8 „ └ „
4·0 „ T „	



In girders with top and bottom flanges take a = area of flange in tension plus $\frac{1}{6}$th of area of web. In built girders, the horizontal table of the angle irons should be treated as flange, and the vertical table as web.

In T or L girders, whether the flange be in tension or compression, take a = the web portion situated above or below the centre of gravity of the section, as the case may be.



NOTE.—These being only rough approximations, experiment should be resorted to in important cases to find the correct value of C, which will vary according to the relative proportions of the flange and web.

For rolled joists and girders of STEEL the above values of C may be increased by one-half.

In all girders the rivet holes crossed by the portion of the section in tension should be deducted.

To prevent lateral flexure, the width of the compression flanges should not be less than $\frac{1}{30}$th to $\frac{1}{40}$th of the span, and in most cases "feathers," or stiffening pieces, are required to supply the deficiency in the lateral stiffness of the girder.

The crushing strength per square inch of ordinary wrought iron may be assumed at 16 tons, and the ultimate tensile strength at 20 tons, or as 1 to 1·25. This would be the proper ratio for the sectional areas of the flanges, if it were not that wrought iron in compression commences to yield by crippling long before the ultimate tensile strength is attained, consequently practical engineers recommend 1 to 1·5 as the best proportion between the tension and compression flanges. When the flanges of plate girders are equal a deduction from that in tension should be made in calculating the ultimate strength. The ultimate strength of ordinary steel, both in tension and compression, is from 30 to 35 tons per square inch.

Thickness of the web of a plate girder depends on

the strength required to resist the tendency to buckle near its supports owing to the vertical and horizontal shearing forces. The amount of these forces, which is a maximum at the piers, though it may be greater at one pier than at the other if the girder is unequally loaded, will always be equal in a vertical or horizontal direction to the load supported by the pier, and as the resultant is transmitted at an angle of 45° buckling tends to occur in that direction. The resistance of the web, as imagined by some writers, may be calculated as a pillar fixed at both ends and equal in length to the vertical depth multiplied by the $\sqrt{2}$, i.e. by 1·414. For small plate girders as used in ordinary building, the thickness of the web need seldom exceed $\frac{3}{8}$ inch at the centre and $\frac{1}{2}$ inch at the piers.

Iron rivets are frequently used for steel plates, they should, however, be stouter than for iron plates of the same thickness.

It is usual to camber a riveted girder, so that on receiving the permanent load it may become nearly horizontal.

If the required rise or camber in the middle = E in inches, d being in inches and L in feet, as before, we have,

$$E = K \frac{L^2}{d}$$

For wrought-iron girders uniformly loaded, and of uniform section throughout the length, K = ·018.

For girders when the section is made to vary so that the girder will be of uniform strength throughout, K = ·021.

The Factor of Safety for a *dead* load on girders of which the length does not exceed 14 times the depth

$$= \frac{W}{4}$$

When the length exceeds 14 times the depth, the girder ceases to be sufficiently rigid under that proportion of the breaking load, and usually yields by buckling, in which case the *factor* should be increased approximately as follows:

When depth $=$	$\frac{L}{15}$	factor of safety $=$	4·3.
”	$\frac{L}{16}$	”	4·6.
”	$\frac{L}{17}$	”	4·9.
”	$\frac{L}{18}$	”	5·2.
”	$\frac{L}{20}$	”	5·7.

For greater ratios of length to depth, the load and deflection should be calculated according to the formulæ for stiffness.

The factor of safety for live loads is usually taken at one-half more than for dead loads.

NOTE.—In girders of considerable dimensions, and beyond the range of experiment as to cross breaking, engineers proportion the quantity of metal in the flanges to the calculated stress arising from the load, by allowing in wrought-iron 1 inch of iron to every 5 tons of tensile stress, and 1 inch to every 4 tons of compressive stress; and in steel, 1 inch to every $6\frac{1}{2}$ tons both in tension and compression.

The horizontal stresses on the top and bottom flanges are for a girder supported at the ends and loaded on the middle (see p. 11),

$$S = \frac{W L}{4 D}$$

When the load is distributed,

$$S = \frac{W L}{8 D}$$

The stress and load represented by S and W, and the length and depth represented by L and D, being in the same terms respectively.

In a deeper girder it becomes necessary to take into consideration the stresses on the web, or diagonal bars, if it be an open girder. These stresses vary with the position of the load, being least at the point of its application and greatest at the points of support. Thus,

	Pier, No. 1.	Pier, No. 2.	At load.
For a central load	$\frac{W}{2}$	$\frac{W}{2}$	$\frac{W}{2}$
For a uniformly distributed load.. ..	$\frac{W}{2}$	$\frac{W}{2}$	nil.

In the case of brackets or beams fixed at one end and loaded at the other, the vertical stresses on the web equal W throughout, but with a distributed load they are nothing at the free end, and equal W at the point of support. When the web is composed of lattice or diagonal bars, the stresses on them are increased in the ratio of the length of the bars to the depth of the girder.

Rolled Iron Joists.

Total Depth.	Width of Flanges.	Thickness of Flanges.	Thickness of Web.	Weight per foot run.	Safe distributed load for a bearing of 1 foot.
inches.	inches.	inch.	inch.	lbs.	tons.
$3\frac{1}{8}$	$1\frac{5}{8}$	·25	·20	5	4 6
3	3	·34	·27	10	10·1
4	2	·35	·28	7	10·2
4	3	·39	·29	12	15·9
$4\frac{3}{4}$	2	·35	·28	8	12·7
5	3	·43	·32	13	22·7
5	$4\frac{1}{2}$	·48	·40	23	36·4
$5\frac{1}{2}$	2	·44	·36	10	16·6
$5\frac{1}{2}$	$2\frac{3}{4}$	·43	·36	13	24·1
6	5	·58	·46	30	60·6
$6\frac{1}{4}$	2	·46	·30	11	22·2
$6\frac{1}{4}$	$2\frac{1}{4}$	·45	·32	13	24·3
$6\frac{1}{4}$	$3\frac{1}{8}$	·47	·38	18	33·8
7	$2\frac{1}{4}$	·43	·33	14	27·4
7	$3\frac{1}{2}$	·48	·34	19	42·5
8	$2\frac{1}{2}$	·48	·42	15	40·6
8	4	·47	·40	21	56·4
8	5	·58	·48	29	82·7
$9\frac{1}{4}$	$3\frac{3}{4}$	·50	·46	24	69·6
$9\frac{1}{2}$	$4\frac{1}{2}$	·57	·47	30	90·8
10	$4\frac{1}{2}$	·60	·50	32	103·0
10	$4\frac{3}{4}$	·70	·65	36	127·7
10	6	·70	·65	46	153·9
12	5	·77	·46	42	167·5
12	6	·91	·59	56	232·6
14	6	·80	·58	59	251·9
16	6	·87	·60	63	319·0

To find the safe distributed load for ANY LENGTH not exceeding 20 times the depth, DIVIDE the load in the last column by the distance between the supports in feet. When over 14 times the depth, the joists must have some lateral stiffening.

Buckled Plates.

d = Depth in inches to which the plate is buckled, usually about $\frac{1}{24}$th of span.
t = Thickness of the metal in inches.
W = Crushing weight in tons distributed.

These plates are usually made 3 feet and 4 feet square, and in thickness of metal up to $\frac{3}{8}$th of an inch.

For plates 3 feet square, and fastened all round the edges.

$W = d\,t^2 \times 165$ for wrought iron, and by 330 for soft puddled steel .

Plates 4 feet square would have less strength. According to the maker of Mallet's buckled plates it would be in the inverse ratio of the length of bearing.

The *central* load which crushes a buckled plate is about $\frac{1}{3}$rd of a uniformly distributed load.

A buckled plate merely supported all round is about one-half as strong as one fastened all round and when two opposite sides are left unfastened the resistance is reduced in the ratio of 8 to 5.

Corrugated Iron.

b = Breadth. } In inches.
d = Depth. } In inches.
t = Thickness of iron. } In inches.
L = Length of bearing in feet.
w = Breaking weight in lbs. on the middle.

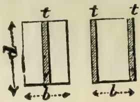
$$w = 4000 \frac{b\,d\,t}{L}.$$

When the thickness is less than 20 S.W.G., the pitch or distance apart of the corrugations is usually 3 inches instead of 5 inches.

The strength is increased by riveting strips of iron across the corrugations to prevent spreading, also when the edges at the sides are down instead of up.

GIRDERS OF WOOD WITH WROUGHT-IRON FLITCHES.

b = Breadth.
d = Depth.
t = Thickness of iron flitch.
} In inches.
L = Length of bearing in feet.
W = Breaking weight in cwts. on the middle.



$$W = \frac{d^2}{L}(Cb + 30t)$$

C = 4·0 teak.
= 3·7 oak, English or Baltic.
= 3·2 „ Canadian.
= 3·0 Northern pine, Memel and Dantzic.
= 2·8 American pine and spruce.
= 2·2 elm.

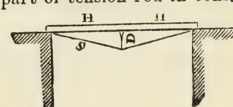
The thickness of the iron flitch should be about $\frac{1}{12}$th that of the wood for fir and pine, and about $\frac{1}{10}$th for oak.

BEAMS OF WOOD TRUSSED WITH WROUGHT IRON.

L = Length in feet
D = Depth in feet
} Measured from the points of intersection of stay, tension rod, and top beam.
W = Load in tons, uniformly distributed.
H = Horizontal thrust on beam in tons.
S = Strain on inclined part of tension rod in tons.

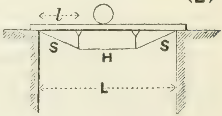
$$H = \frac{W L}{8 D}$$

$$S = \sqrt{H^2 + \frac{W^2}{16}}$$



When the truss is unbraced, and has more than one stay, as sketch, and the load = W is placed on the middle of the beam,

(2)

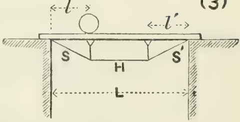


$$H = \frac{L\,W}{4\,D}$$

$$S = \frac{H}{l}\sqrt{l^2 + D^2}$$

When the load is placed over one of the stays,

(3)



$$H = \frac{l\,W}{D\,L}(L - l)$$

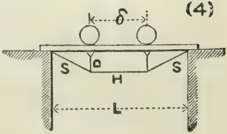
$$S = \frac{H}{l}\sqrt{l^2 + D^2}$$

$$S' = \frac{H}{l'}\sqrt{l'^2 + D^2}$$

In this case there is an upward pressure on the beam at the unloaded stay $= \frac{H\,D}{l'}$ to resist which the strength should be calculated as a beam of the length $L - l$ fixed at one end and supported at the other, and loaded with $\frac{H\,D}{l'}$ at the point over the stay.

When a load = W is placed on each of the stays,

(4)



$$H = \frac{W\,(L - \delta)}{2\,D}$$

$$S = \sqrt{H^2 + W^2}$$

To resist the stresses S S′ and H with safety, allow *one inch* of sectional area in the tie rods for every five tons of stress.

The stay D being in compression, should be calculated as a pillar capable of resisting the thrust to which it is exposed, viz. in the case of No. 1, *half* the load when distributed, or the whole if placed on the centre. In the case of No. 2, half the load; and in Nos. 3 and 4, the whole of the load resting on each stay.

The top beam, although in compression from the stress H, should be capable of supporting the load between the stays, or the stay and the pier; in which case it will be more than strong enough to resist the thrust H.

Transverse Stiffness.

$$\left.\begin{array}{l} b = \text{Breadth} \\ d = \text{Depth} \\ \Delta = \text{Deflection} \end{array}\right\} \text{in inches.}$$

E = Coefficient of transverse elasticity.
I = Moment of inertia in inches.
L = Length in feet.
w = Load in lbs.

Beams supported at the ends, and loaded on the middle.

Formula for deflection at centre, applicable to any beam of uniform cross section

$$\Delta = 36 \frac{L^3 w}{E I}$$

Beams of rectangular section,

$$\Delta = \frac{a\,L^3\,w}{40\,b\,d^3}$$

Beams of circular section,

$$\Delta = \frac{a\,L^3\,w}{23 \cdot 6\,d^4}$$

d being the diameter in inches.

When Δ is limited to $\frac{1}{40}$th of an inch for every foot in the total length,

$d = \sqrt[3]{\frac{a\,L^2\,w}{b}}$ = depth of beam in inches.

$o = \frac{a\,L^2\,w}{d^3}$ = breadth in inches.

$w = \frac{b\,d^3}{a\,L^2}$ = load in lbs., sustained by a beam without deflecting more than $\frac{1}{480}$th part of the length.

$d = \sqrt[4]{1 \cdot 7\,a\,L^2\,w}$ = diameter of cylindrical beam.

$d = \sqrt[3]{\frac{a\,L^2\,w\cos. c}{b}}$ = depth of rectangular beam when inclined to the horizon at the angle c.

$w = \frac{b\,d^3}{a\,L^2\cos. c}$ = load in lbs. sustained by an inclined beam.

Note. - If the deflection be limited to *one-half* of $\frac{1}{40}$th of an inch per foot, multiply a by 2; if one-third, multiply by 3, and so on.

TABLE OF CONSTANTS FOR DEFLECTION.

Material.	Coefficient of Elasticity. E.	Value of *a*.
WOOD.	lbs.	
Ash	1,646,000	·0105
Anjilli (*A. hirsuta*)	—	—
Beech	1,316,000	·0131
Birch	1,645,000	·0105
Cedar (*C. Libani*)	486,000	·0355
„ (*C. odorata*)	290,000	·0595
„ (*C. Australis*)	—	—
„ (*C. toona*)	1,784,000	·0097
Chestnut	925,000	·0187
Elm	816,000	·0212
Eucalyptus, Iron Bark	1,000,000	·0173
„ Blue Gum	—	—
„ Stringy Bark	1,709,000	·0101
„ Jarrah	1,157,000	·0149
Fir, Spruce, Baltic (*A. excelsa*)	1,500,000	·0115
„ „ American (*A. alba*)	1,244,000	·0139
Greenheart, British Guiana	1,200,000	·0144
Hal Mendora, Ceylon	1,530,000	·0113
Ironwood, Ceylon	2,100,000	·0082
Jack (*Artocarpus integrifolia*)	1,810,000	·0095
Kauri, New Zealand	1,982,000	·0087
Larch	905,000	·0191
Mahogany, Honduras	1,585,000	·0109
„ Spanish	1,256,000	·0137
Mango, India	1,347,000	·0129
Mora, British Guiana	1,019,000	·0169
Nim, India	1,154,000	·0149
Oak, English	1,452,000	·0112
„ Baltic	1,646,000	·0105
„ Canadian	1,920,000	·009
Pine, Northern (*P. sylvestris*), Riga	1,516,000	·0114
„ „ „ Memel	1,942,000	·0089
„ American Red (*P. rubra*)	1,168,000	·0148
„ „ White (*P. strobus*)	1,571,000	·011
„ „ Pitch (*P. Australis*)	1,224,000	·0141

TABLE OF CONSTANTS—*continued.*

Material.	Coefficient of Elasticity. E.	Value of a.
WOOD—*continued.*		
Poon, India	1,690,000	·0102
Sâl, India	2,144,000	·008
Sissoo, India	1,518,000	·0013
Sycamore	1,036,000	·0167
Tal Palmyra, Ceylon	2,810,000	·0061
Teak, Burmah	1,943,000	·0089
METALS, &c.		
Iron, Wrought	28,000,000	·0006
„ Cast	16,000,000	—
Steel.. .. .. from	29,000,000	·0006
to	42,000,000	·0004
Brass, Cast	9,170,000	·0019
Copper Bars	12,000,000	·0014
Glass	8,000,000	·0022
Slate	13,000,000	·0013

Comparative values of Δ *according to position of load and mode of fixing the beam:*

Beam supported at both ends and loaded on the middle .. .. $= \Delta$

Ditto, loaded uniformly .. .. .. $= \frac{5}{8}\Delta$

Beam *fixed* at both ends, and loaded on the middle .. .. $= \frac{1}{4}\Delta$

Ditto, loaded uniformly .. .. $= \frac{1}{8}\Delta$

Beam fixed at one end, and loaded at the other .. .. $= 16\,\Delta$

Ditto, and loaded uniformly .. .. .. $= 6\,\Delta$

The deflection of a square or rectangular beam is to that of a cylindrical one as 1 is to 1·7.

The deflection of a square beam is the same, whether the

diagonal or a side be vertical, although in the latter case it would require 1·414 times greater load to break it.

It will be seen by the foregoing table, that in beams supported at both ends, the deflection caused by a distributed load is the same as that produced by $\frac{5}{8}$ths of the same load concentrated at the middle, and in a semi-beam *fixed* at one end, the same effect is produced by $\frac{3}{8}$ths of the distributed load concentrated at the free end of the beam.

In the case of beams supported at both ends and loaded on the middle, and also of semi-beams fixed at one end and loaded at the other, the maximum deflection is increased by *one-half* if the strength and depth be made uniform throughout the length, and is *doubled* if the breadth be kept uniform, and the depth made to vary according to the strength as compared with beams of uniform cross section.

Deflection of Wrought-iron Flanged Girders.

For wrought-iron girders of uniform strength with top and bottom flanges,

$$\Delta = \frac{18\,L^2}{d}\,(e + e^1)$$

L and Δ being the length in feet and deflection in inches, as before.

d = the depth in inches between the centres of gravity of the flanges.

e = the extension for every ton per square inch within the limits of elasticity (usually taken at from $\frac{8}{100000}$ to $\frac{1}{10000}$ part of the length) multiplied by the average tonnage per square inch on the extended flange.

e' = the compression (usually taken at $\frac{1}{10000}$ of the length per ton per square inch), multiplied by the tonnage per square inch on the compressed flange.

When the web is a solid plate, add $\frac{1}{6}$th of its area to that of each flange in calculating the tonnage per square inch.

FLOORS.

(TREDGOLD.)

b = Breadth in inches.
d = Depth in inches.
L = Length in feet.

GIRDERS OF WOOD.

10 feet apart in floors.

$$d = \sqrt[3]{\frac{L^2}{b}} \times 4 \cdot 2 \text{ for Northern pine, or by } 4 \cdot 34 \text{ for oak.}$$

$$b = \frac{L^2}{d^3} \times 74 \text{ pine, or } 82 \text{ oak.}$$

To obtain the maximum stiffness, b should $= \frac{5}{7}d$.

Wood girders should not be built into the wall, but an open space left around their ends for ventilation. The bearing on the wall should be from 9 to 12 inches, according to length.

BINDING JOISTS.

6 feet apart.

$$d = \sqrt[3]{\frac{L^2}{b}} \times 3 \cdot 42 \text{ for pine, or } 3 \cdot 53 \text{ for oak.}$$

$$b = \frac{L^2}{d^3} \times 40 \text{ for pine, or } 44 \text{ for oak.}$$

A bearing on the wall of 6 inches is sufficient for binding joists.

NOTE.—Should the distance apart for girders or binding joists be greater or less than stated, the breadth b should be varied in proportion.

The scantlings of binding joists that have to carry a ceiling only may be found by the rule for ceiling joists, by using the multipliers 1·2 for Northern pine, and 1·25 for oak, instead of 0·64 and 0·67.

Single or Bridging Joists.

12 inches from centre to centre.

$$d = \sqrt[3]{\frac{L^2}{b}} \times 2\cdot2 \text{ pine, or } 2\cdot3 \text{ oak.}$$

Trimmers are usually calculated as binding joists of the same bearing.

Trimming joists are taken as single joists with the addition of $\frac{1}{8}$ inch to their thickness for every joist carried by the trimmer.

When the bearing of single joists exceeds 8 feet, they should be strutted to prevent their twisting, and for each increase of 4 feet in the bearing there should be an additional row of struts.

Fifteen feet is the maximum bearing for which single joists can be used without affecting the stiffness of the floor.

Scantlings for Single Joists of Baltic Pine.

Distance from middle to middle = 12 inches.

Length of Bearing in feet.	Breadth in inches.			
	$1\frac{3}{4}$	2	$2\frac{1}{2}$	3
	Depth.	Depth.	Depth.	Depth.
5	$5\frac{1}{2}''$	$5\frac{1}{4}''$	$4\frac{3}{4}''$	$4\frac{3}{8}''$
6	6	$5\frac{3}{4}$	$5\frac{3}{8}$	5
7	$6\frac{3}{4}$	$6\frac{1}{2}$	6	$5\frac{1}{2}$
8	$7\frac{1}{2}$	7	$6\frac{1}{2}$	$6\frac{1}{4}$
9	$7\frac{7}{8}$	$7\frac{1}{2}$	$6\frac{7}{8}$	$6\frac{1}{2}$
10	$8\frac{1}{2}$	8	$7\frac{1}{2}$	7
12	$9\frac{3}{4}$	$9\frac{1}{2}$	$8\frac{1}{2}$	8
14	$10\frac{1}{2}$	10	$9\frac{1}{2}$	9
16	$11\frac{1}{2}$	11	$10\frac{1}{2}$	$9\frac{3}{4}$
18	$12\frac{1}{2}$	12	$11\frac{1}{4}$	$10\frac{1}{2}$
20	$13\frac{1}{2}$	13	12	$11\frac{1}{4}$
25	$15\frac{1}{2}$	15	14	13

Ceiling Joists.

12 inches from centre to centre.

$$d = \frac{L}{\sqrt[3]{b}} \times 0 \cdot 64 \text{ pine, or } 0 \cdot 67 \text{ oak.}$$

$$\sqrt[3]{1\tfrac{1}{2}} = 1 \cdot 145$$
$$\sqrt[3]{1\tfrac{3}{4}} = 1 \cdot 205$$
$$\sqrt[3]{2} = 1 \cdot 260$$
$$\sqrt[3]{2\tfrac{1}{2}} = 1 \cdot 357$$

2 inches is the usual thickness (b) for ceiling joists, in which case the depth will equal $\frac{1}{2}$ inch per foot in length of bearing.

Pine is better for ceiling joists than oak, as the latter is more liable to warp in seasoning.

Lintels over Openings.

Take 1 inch in depth for every foot of bearing, and if no relieving arch over, take $1\frac{1}{4}$ inch for every foot of bearing.

Wall Plates and Templets under Floor Girders.

			Size of Plate, &c.	
Bearing of Girder,	20 feet	..	$4\frac{1}{2}$ in. ×	3 in.
” ”	30 ”	..	6 in.	4 in.
” ”	40 ”	..	$7\frac{1}{2}$ in.	5 in.

NOTE.—Floors and ceiling joists should be fixed about $\frac{3}{4}$ of an inch higher in the middle than at the sides of a room for every 20 feet span, measured along the length of the girder or joist, to allow for settlement.

The Weight which Floors should be Calculated to Sustain.

	Per foot superficial.
Ordinary dwelling-house floors, including the weight of the floor itself	$1\frac{1}{4}$ cwt.
Public buildings, lecture rooms, &c.	$1\frac{1}{2}$,,
Warehouses, factories, &c.	$2\frac{1}{2}$ to 4 ,,

RESISTANCE TO SHEARING.

Metals.

	Per square inch.
Steel, cast	41 tons.
,, bars, hammered	30 ,,
,, rivets	30 to 40 ,,
Wrought-iron bars	18 ,,
,, plates, in punching	24 ,,
,, rivets	22 ,,
Cast iron	12 to 17 ,,
Copper	14 ,,

Wood.

With the fibres.

Oak, English	700 lbs.
Pine, Northern (*P. sylvestris*)	500 ,,
,, American, white (*P. strobus*)	430 ,,
Fir, Spruce (*A. excelsa*)	—
,, ,, (*A. alba*)	420 ,,
,, ,, (*A. Canadensis*)	490 ,,

Across the fibres.

Oak, English	3000 ,,
Pine, Northern	—
,, American, red	800 ,,
Fir ,, (*A. alba*)	600 ,,
Larch	900 ,,

NOTE.—According to Kirkaldy's experiments the resistance to shearing in both wrought iron and steel is on an average $\frac{1}{4}$th less than the resistance to tension.

TORSION.

d = Diameter of shaft in inches.

r = Radius of wheel or length of arm in inches at the end of which W acts.

W = Weight in lbs. required to break the shaft by twisting.

Then for

STRENGTH OF SHAFTS.

Solid cylinder $d = \sqrt[3]{\frac{W\,r}{C}}$; $W = \frac{C\,d^3}{r}$

Solid square $S = \sqrt[3]{\frac{7\,W\,r}{10\,C}}$; $W = \frac{10\,C\,S}{7\,r}$

S being the side in inches.

Hollow cylinder d $= \sqrt[3]{\frac{W\,r}{C\,(1 - n^4)}}$; $W = C\,\frac{d^4 - d'^4}{d}$

d' being the internal diameter.

and $n = \frac{d'}{d} = \frac{\text{int. diam.}}{\text{ext. diam.}}$

C = 15600 cast steel.
9600 wrought iron.
7800 cast iron.
2400 brass.
2112 wrought copper.
— oak.
— fir and pine.

For axles with a steady motion, as in crabs, pumps, &c., take the working load $= \frac{W}{6}$. For cranes and other machinery liable to jerks, take the working load $= \frac{W}{10}$.

Stiffness of Shafts.

L = Length of shaft in feet.
θ = Angle of torsion in degrees within the elastic limit.
W = Weight in lbs. to twist the shaft through θ degrees.

Then for solid cylinders,

$$d = \sqrt[4]{\frac{L\,r\,W}{C\,\theta}}$$

$$W = \frac{C\,\theta\,d^4}{L\,r}$$

$$\theta = \frac{L\,r\,W}{C\,d^4}$$

Hollow cylinders,

$$W = \frac{\theta\,C\,(d^4 - d'^4)}{L\,r}$$

$$\theta = \frac{W\,L\,r}{C\,(d - d'^4)}$$

d' being the internal diameter in inches.

$$\begin{aligned} C &= 3200 \text{ cast steel.} \\ &= 1700 \text{ wrought iron.} \\ &= 1500 \text{ cast iron.} \\ &= 20 \text{ oak.} \\ &= 15 \text{ fir and pine.} \end{aligned}$$

$\frac{1}{12}$th of a degree per foot in length of the shaft is considered the maximum amount of twisting to be allowed in practice consistent with stiffness, in which case the formula becomes

$$d = \sqrt[4]{\frac{12\,r\,W}{C}}\,;\ W = \frac{C\,d^4}{12\,r}$$

Fairbairn fixes the angle of torsion at $\theta = \frac{2284\,L}{1000\,d}$ which should not be exceeded.

Shafts should be calculated by the rules for *strength* (working load) and *stiffness*, the greatest diameter being adopted.

Shafts should also have sufficient strength and stiffness to resist bending, as calculated by the rules for transverse stress, the deflection being limited to $\frac{1}{100}$th of an inch for every foot in length of the shaft.

RESISTANCE TO COMPRESSION.

WOOD.

MEAN CRUSHING WEIGHT OF SHORT SPECIMENS— per square inch.

In the direction of the fibres.	Tons.
Alder	3·06
Ash	3·50
„ American	2·40
Beech	3·80
Birch	2·72
„ American	4·50
Blue Gum, Australia	3·20
Box	4·60
Cedar of Lebanon	2·56
Crab	3·19
Ebony, West Indian	8·40
Elder	4·25
Elm	2·50 to 3·50
Fir, Norway Spruce (*A. excelsa*)	2·50
„ Hemlock (*A. Canadensis*)	2·46
Greenheart, British Guiana	5·80
Hornbeam	3·41
Iron Bark, Australia	4·42
Jarrah „	3·20
Larch	2·48
Lignum Vitæ	4·25
Locust	3 35
Mahogany, St. Domingo	3·00
„ Honduras	2·80
Maple, American	2·70
Mora, British Guiana	3·80
Oak, English and Dantzic	3·20

Wood—*continued.*

	Tons.
Oak, Dantzic, very dry	3·45
„ Canadian	2·68
„ American White	2·97
„ „ Red	2·68
„ „ Live	3·54
Pine, Northern (*P. sylvestris*), Memel	2 90
„ „ „ Dantzic	2·95
„ „ „ Riga	2·30
„ White (*P. strobus*), American	1·85
„ Red (*P. rubra*) „	2·29
„ Pitch (*P. Australis*) „	3·02
„ Kauri, New Zealand	2·87
Poplar	2·29
Sâl, India	3·80
Sycamore	3·20
Stringy Bark, Australia	3·12
Teak, Burmah	3·80
Walnut	3·21
„ White or Hickory, American	4·38
„ Black	2·50
Willow	2·73

Force across the fibres required to compress the wood $\frac{1}{20}$th of an inch—per square inch.

Ash, American	1·03
Chestnut	·42
Fir, Spruce, (*A. alba*)	·22
„ Hemlock (*A. Canadensis*)	·27
Lignum Vitæ	2·5
Locust	·94
Mahogany, Honduras	·58
„ St. Domingo	1·92

WOOD—*continued.*

	Tons.
Maple, American	·91
Oak, English	·90
„ American	·84
„ „ White	·89
„ „ Live	2·28
Pine, Northern, Memel	·60
„ White (*P. strobus*), American	·27
„ Georgia (*P. Australis*)	·76
„ Ohio	·56
Walnut, Black, American	·71
„ Hickory „	1·39

PILLARS AND STRUTS OF WOOD.
(RANKINE.)

d = Diameter of cylindrical, or least thickness of rectangular pillars in inches.
F = Crushing force in tons per square inch (short specimens).
l = Length in inches.
S = Sectional area in square inches.
W = Breaking weight in tons.

Flat bedded at both ends.

$$W = \frac{\frac{F\,S}{}}{1 + \frac{l^2}{a\,d^2}}$$

a = 250 for square or rectangular sections.
a = 187 for circular ditto.

When rounded at one end and flat bedded at the other take $\frac{9}{16}a$.

When rounded at both ends take $\frac{1}{4}a$

TABLE showing decrease in strength of wood posts when flat-bedded, due to an increase of length.

$$W = C \times (FS).$$

Ratio of Length to Least Side or Diam.	Value of C.		Ratio of Length to Least Side or Diam.	Value of C.	
	Square or Rectangular Sections.	Circular Sections.		Square or Rectangular Sections.	Circular Sections.
4	1·000	1·000	24	·303	·245
6	·943	·916	26	·270	·217
8	·833	·745	28	·242	·193
10	·714	·652	30	·217	·172
12	·635	·565	32	·196	·154
14	·561	·488	34	·178	·139
16	·494	·432	36	·162	·126
18	·436	·366	38	·148	·115
20	·385	·319	40	·135	·105
22	·341	·279	42	·124	·096

The strongest form of section for a wood pillar is the square.

Green or wet timber is much inferior in strength to dry or seasoned timber (only ½, according to Hodgkinson).

NOTE.—Pillars of wood are seldom fixed in the sense used by Hodgkinson and others, but merely flat bedded, in which case the strength is between that of pillars firmly fixed and those rounded at both ends. Very long pillars (over 30 diameters), if not firmly fixed, should be considered as rounded at the ends.

Pillars of wood with flat ends yield wholly by crushing when the length is under 10 diameters, and partly by crushing and partly by bending when the length is between 10 and 30 diameters; above the last proportion they yield wholly by bending.

The formula applies strictly to pillars which yield by bending only, and approximately to shorter pillars; for those under 10 diameters in length the strength is nearly W=FS; but the results will be influenced chiefly by the nature of the wood and the straightness of its grain.

$$\text{Factor of safety} = \tfrac{1}{10}.$$

METALS.

MEAN CRUSHING WEIGHT OF SHORT SPECIMENS— per square inch.

	Tons.
Iron, wrought	16
„ cast, 2nd melting	36
Steel, cast	80
„ „ hardened	130
„ puddled	50
„ „ plates	33
Copper, cast	5
Brass „	$4\frac{1}{2}$

STRUTS OF WROUGHT IRON.

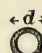
When fixed at the ends

$$W = \frac{16\,S}{1 + \dfrac{l^2}{a\,d^2}}$$

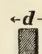
S being the sectional area of the metal in inches.

a = 6000 for a thin (less than $\frac{d}{8}$) square tube.

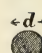
= 4500 for a thin round tube.



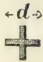
= 3000 for a solid rectangle or square.



= 2250 for a solid cylinder.

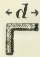


$= 1500$ for a cross with equal arms.



$= 1500$ for **T** section with equal top and web.

$= 1500$ for an angle with equal sides.



$= 3000 \dfrac{S}{S + b}$ for a section, as sketch.

$= 1934$ channel as sketch.

S being the sum of the areas of the flanges, and b that of the web.

When round or jointed at the ends, take $\dfrac{a}{4}$

Factor of safety $= \frac{1}{10}$

Note.—When the length of wrought-iron built cells or tubes does not exceed 15 or 20 times their width, they yield by bulging or buckling of the plates, not by the flexure of the pillar; within this limit the strength of the tube is nearly independent of its length.

The ultimate resistance of a single square cell to crushing by the buckling or bending of its sides, when the thickness of the plates is not less than $\frac{1}{30}$th of the diameter of the cell, as determined by Fairbairn and Hodgkinson, is 12 tons per square inch of the iron in the section.

But when a number of cells exist side by side in one girder, their stiffness is increased, and their ultimate resistance to a thrust may be taken at 14 to 16 tons per square inch. The latter coefficients apply also to cylindrical cells.

Pillars of Cast Iron,

(Hodgkinson.)

Ends flat and fixed.

d = diameter in inches.
L = Length in feet.
W = Crushing weight in tons.

When L exceeds 30 diameters.

$$\text{Solid pillars } W = 42\,\frac{d^{3\cdot5}}{L^{1\cdot6}}$$

$$\text{Hollow pillars } W = 42\,\frac{d^{3\cdot5} - d'^{3\cdot5}}{L^{1\cdot6}}$$

d' being the internal diameter in inches.
When the ends are rounded take $\frac{1}{3}$ W.
When L is less than 30 diameters—
W = Crushing weight, as above, in tons.
W′ = Crushing weight of short pillar in tons.
S = Sectional area of solid part of pillar in inches.

$$W' = \frac{36\,W\,S}{W + 27\,S}$$

In hollow pillars the thickness of metal should not be less than $\frac{d}{12}$.

Gordon's Formulæ.

Take l = length in inches.

Then for ROUND HOLLOW PILLARS, when the ends are flat bedded.

$$W = \frac{36\,S}{1 + \frac{l^2}{400\,d^2}}$$

When the section is a HOLLOW SQUARE, and the diagonal $= d$, or the section is similar to a H and $d =$ one of the parallel sides,

$$W = \frac{36\,S}{1 + \frac{3\,l^2}{800\,d^2}}$$

When the section is a CROSS, d being the diameter from end to end of the shortest pair of arms,

$$W = \frac{36\,S}{1 + \frac{3\,l^2}{400\,d^2}}$$

When the ends are hinged take $100\,d^2$ instead of $400\,d^2$, and $200\,d^2$ instead of $800\,d^2$, in the above formulæ.

In order to give lateral stiffness to flat-ended pillars, the ends should spread so as to form a capital and base, and when they are in two or more lengths the joints should be made truly plane and perpendicular to the axis.

Factor of safety $= \frac{1}{6}$th for short pillars, to $\frac{1}{10}$th for long pillars.

Pillars of Steel (Strong).

Round and hollow, ends flat bedded—

$$W = \frac{50\,S}{1 + \frac{l^2}{1000\,d^2}}$$

Ditto, ditto, solid, and ditto—

$$W = \frac{50\,S}{1 + \frac{l^2}{800\,d^2}}$$

Factor of safety $\frac{1}{10}$th.

(From Hodgkinson's Experiments.)

1. Long pillars with ends flat and firmly fixed are three times stronger than those with the ends rounded (i.e. movable). This ratio decreases when the pillars (cast iron) are shorter than 30 diameters, being about $1\frac{1}{2}$ times when the length is only 12 diameters.

2. Pillars with one end round and the other flat are in strength a mean between those with both ends round and both flat.

3. A long pillar with ends firmly fixed is equal in strength to a pillar of half the length with the ends movable.

4. Long uniform pillars break in the middle when the ends are rounded; at the middle and also near each end when both ends are fixed; and at about $\frac{1}{3}$rd of the length from the movable end, when one end is fixed and the other movable.

5. Discs on the ends add very slightly to the strength of flat-ended pillars.

6. Enlarging the diameter in the middle of solid pillars with rounded ends increases the strength slightly (about $\frac{1}{7}$th).

7. Enlarging the diameter of hollow cast-iron pillars in the middle or at one end does not increase their strength.

8. Solid square pillars usually break in the direction of their diagonals.

9. Pillars with flat ends yield wholly by crushing when the length does not exceed for cast iron 5 diameters, and for wrought iron 10 diameters; and partly by crushing and partly by bending when the length is between 5 and 30 diameters for cast iron, and 10 to 60 diameters for wrought iron. In these cases the results obtained by the foregoing formulæ must be considered as approximate only.

10. The resistance of *long* plates of wrought iron (over 60 times the width) to bending is as the 2·878 power of the thickness multiplied by the breadth, and divided by the square of the length. This does not apply to tubes which fail by buckling.

Note.—Very few experiments have been made on pillars of the size usually adopted in practice. Those of Hodgkinson for the most part did not exceed 60 inches in length, and $1\frac{1}{2}$ inches in diameter, therefore too much reliance should not be placed on the formulæ derived from these experiments, nor on that of Euler, which contemplates a condition of things rarely met with in practice.

The following tables of the strength of cast-iron hollow columns were compiled after a full consideration of existing formulæ and the conditions usually met with in practice. They have been in use by the profession for more than 35 years.

Table of Hollow Cast-iron Columns.

The ends being flat and fixed, calculated at about $\frac{1}{10}$th of the breaking weight as indicated by experiment.

Thickness of metal = $\frac{1}{2}$ inch.

External Diameter in inches.	Length in feet.								
	6	8	10	12	14	16	18	20	25
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
3	5·8	4·0	3·2	2·3	1·8	1·4	1·2	1·0	·7
3½	8·2	5·9	5·1	3·6	2·7	2·3	1·9	1·5	·9
4	10·9	8·1	6·1	4·7	3·6	3·4	2·8	2·0	1·5
4½	13·8	10·6	8·1	6·5	5·0	4·4	3·9	3·1	2·0
5	16·8	13·3	10·4	8·3	6·7	5·4	5·0	4·0	2·7
5½	19·8	15·3	12·9	10·5	8·5	7·0	6·2	5·2	3·5
6	22·9	19·0	15·5	12·7	9·5	8·7	7·3	6·2	4·3
6½	26·0	22·0	18·3	15·2	12·4	10·7	9·1	7·7	5·4
7	29·1	25·0	21·2	17·9	15·1	12·8	10·9	9·3	6·5
7½	32·2	28·1	24·2	20·6	17·6	15·0	12·9	11·1	7·9
8	35·3	31·2	27·1	23·4	20·2	17·4	15·0	13·1	9·4
8½	38·4	34·3	30·2	26·3	22·9	19·9	17·3	15·1	11·0
9	41·4	37·4	33·3	29·4	25·6	22·5	19·7	17·4	12·7
Thickness of metal = $\frac{5}{8}$ inch.									
3	6·9	4·7	3·5	2·6	2·0	1·6	1·3	1·0	·8
3½	9·9	7·1	5·3	4·2	3·2	2·5	2·1	1·8	1·2
4	13·2	9·2	7·3	5·6	4·4	3·9	3·2	2·7	1·8
4½	16·7	12·8	9·9	7·7	6·1	5·5	4·5	3·8	2·6
5	20·4	16·1	12·7	9·1	8·1	7·0	6·0	4·9	3·5
5½	24·1	18·7	15·7	12·8	10·4	8·8	7·5	6·3	4·7
6	28·0	23·2	19·0	15·6	12·8	10·6	9·0	7·6	5·8
6½	31·8	26·9	22·4	18·7	15·2	13·0	11·0	9·4	7·6
7	35·6	30·7	26·0	21·9	18·5	15·6	13·3	11·4	9·0
7½	40·5	34·5	29·7	25·3	21·6	18·4	15·8	13·6	11·0
8	43·4	38·4	33·4	28·8	24·8	21·4	18·5	16·1	13·0
8½	47·0	42·2	37·1	32·4	28·2	24·5	21·3	18·6	15·5
9	51·6	46·1	41·0	36·2	31·5	27·7	24·3	21·3	18·1

CAST-IRON COLUMNS—*continued.*

Thickness of metal = ¾ inch.

External Diameter in inches.	Length in feet.								
	6	8	10	12	14	16	18	20	25
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
3	7·8	5·4	3·8	2·8	2·2	1·7	1·4	1·1	·8
3½	11·3	8·1	6·2	4·4	3·5	2·6	2·1	1·9	1·3
4	15·2	11·3	8·5	6·5	4·8	3·8	3·3	2·8	1·8
4½	19·4	14·9	11·5	8·9	7·2	6·0	5·0	4·1	2·7
5	23·7	18·8	14·8	11·7	9·0	7·7	6·5	5·7	3·8
5½	28·2	21·8	18·4	14·9	12·1	10·2	8·6	7·2	5·3
6	32·8	27·2	22·3	18·3	15·0	12·5	10·5	8·8	6·4
6½	37·3	31·6	26·3	21·9	17·8	15·3	12·0	10·7	8·0
7	41·9	36·1	30·6	25·8	21·7	18·4	15·7	12·6	9·0
7½	46·5	40·6	35·0	29·8	25·4	21·7	18·6	15·6	11·5
8	51·1	45·3	39·3	34·0	29·3	25·2	21·8	18·7	13·7
8½	55·7	49·8	43·8	38·3	33·3	28·9	25·1	21·9	15·9
9	60·3	54·4	48·5	42·8	37·2	32·7	28·7	24·2	18·4
	Thickness of metal = ⅞ inch.								
4	16·1	12·7	9·5	7·3	5·7	4·6	3·8	3·2	2·0
4½	21·9	16·6	12·9	10·1	8·0	6·7	5·5	4·5	3·1
5	26·9	21·3	16·7	13·3	10·7	8·8	7·4	6·1	4·1
5½	32·0	24·8	20·9	16·9	13·7	11·5	9·5	7·8	5·3
6	37·3	31·0	25·4	20·8	17·1	14·2	12·0	10·2	7·0
6½	42·6	36·0	30·1	25·1	20·4	17·5	14·9	12·7	8·8
7	47·7	41·0	34·7	29·2	24·6	20·9	17·8	15·2	10·8
7½	53·3	46·5	40·0	34·1	29·1	24·8	21·3	18·4	13·1
8	58·6	51·9	45·1	39·0	33·6	28·9	25·0	21·8	16·7
8½	64·0	57·2	50·4	44·0	38·2	33·2	28·9	25·2	18·4
9	69·3	62·6	55·7	49·1	42·7	37·5	32·9	28·9	21·2
10	79·9	73·4	66·5	59·5	53·0	47·0	41·7	37·0	27·9
	Thickness of metai = 1 inch.								
4	18·7	13·9	10·4	8·0	6·4	4·8	3·9	3·3	2·3
4½	24·2	18·5	14·3	11·1	8·8	7·1	5·8	4·8	3·2
5	29·9	23·6	18·6	14·8	11·9	9·6	7·6	6·5	4·6
5½	35·6	27·6	23·2	18·9	15·3	12·7	10·3	8·8	6·0
6	41·6	34·5	28·3	23·2	19·1	15·9	13·3	11·3	7·6
6½	47·7	40·3	33·6	28·0	22·8	19·6	16·6	14·2	9·1

CAST-IRON COLUMNS—*continued.*

Thickness of metal = 1 inch—*continued.*

External Diameter in inches.	Length in feet.								
	6	8	10	12	14	16	18	20	25
	tons.	tons.	tons.	tons.	tons	tons.	tons.	tons.	tons.
7	53.7	46.2	39.1	33.0	27.8	23.6	20.1	17.2	11.0
7½	59.7	52.2	44.9	38.3	32.6	27.9	23.9	20.6	13.3
8	65.9	58.3	50.7	43.8	37.7	32.5	28.1	24.4	16.4
8½	71.9	64.3	56.5	49.4	42.9	37.3	32.4	28.3	19.5
9	78.0	70.5	62.7	55.3	48.1	42.3	37.1	32.6	23.0
10	90.2	82.8	75.0	67.1	59.7	53.0	47.0	41.7	31.4
11	102.1	95.1	87.1	79.1	71.4	64.2	57.6	51.6	39.5
12	115.1	107.3	97.0	91.6	82.9	76.0	68.8	62.2	48.4
				Thickness of metal = 1¼ inch.					
4½	28·1	21·5	16·5	12·9	10·2	7·6	6·2	5·2	3·4
5	34·9	27·6	21·7	17·2	13·9	10·8	8·8	7·4	4·6
5½	42·1	32·6	27·5	22·3	18·0	14·6	12·0	10·0	6·8
6	49·4	41·0	33·6	27·5	22·7	18·8	15·8	13·4	8·8
6½	56·8	48·0	40·0	34·4	27·1	23·3	19·8	16·9	11·0
7	64·3	55·4	46·9	39·5	33·3	28·3	24·2	20·6	14·0
7½	71·8	62·7	54·0	46·0	39·3	33·5	28·7	24·8	17·4
8	79·3	70·2	61·1	51·7	45·4	39·1	33·8	29·4	21·2
8½	87·0	77·8	68·4	59·7	51·9	45·1	39·2	34·2	24·8
9	94·5	85·3	75·9	66·9	58·3	51·2	44·9	39·4	28·9
10	109·6	100·7	91·2	81·6	72·6	64·3	57·2	50·7	38·1
11	124·6	115·8	106·2	96·5	87·1	78·2	70·2	63·0	48·3
12	140·6	131·1	118·6	111·9	101·3	92·9	84·0	76·0	59·1
				Thickness of metal = 1½ inch.					
6	56·2	46·6	38·2	31·3	25·9	21·4	18·0	15·3	10·6
6½	64·9	55·0	45·9	38·2	31·1	26·7	22·7	19·4	13·5
7	73·7	63·5	53·7	45·3	38·2	32·4	27·6	23·7	16·7
7½	82·8	72·3	62·3	53·3	45·2	38·6	33·1	28·6	20·4
8	91·6	81·2	70·6	61·0	52·4	45·1	39·0	33·9	24·4
8½	100·7	90·1	79·2	69·1	60·1	52·2	45·4	39·6	28·9
9	109·7	99·1	88·1	77·7	67·6	59·4	52·1	45·7	33·6
10	127·8	117·3	106·3	95·1	84·7	75·1	66·6	59·1	44·4
11	145·7	135·5	124·3	112·9	101·9	91·5	82·1	73·7	56·4
12	164·9	153·6	139·0	131·2	118·8	108·9	98·5	89·1	69·3

CAST-IRON COLUMNS—*continued.*

Solid.

External Diameter in inches.	Length in feet.								
	6	8	10	12	14	16	18	20	25
	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
2	2·3	1·4	1·0	·7	·50	·44	·36	·30	·20
2¼	2·8	2·1	1·5	1·0	·83	·66	·54	·46	·31
2½	4·6	2·9	2·1	1·6	1·21	·95	·80	·66	·56
2¾	6·5	4·0	3·0	2·2	1·72	1·35	1·11	·94	·64
3	8·9	6·0	4·0	3·0	2·30	1·84	1·50	1·28	·88

NOTE.—In the foregoing Table $\frac{1}{10}$th of the breaking load is adopted to allow for imperfections in casting and mode of fixing, the deviation of the line of pressure from the axis of the column, and the effect of lateral forces accidentally applied. If these risks can be obviated, a less proportion, probably $\frac{1}{6}$th or even $\frac{1}{5}$th, might be taken as the safe load. Bracketed capitals on the edges of which the load is made to rest, reduce the strength sometimes to as much as $\frac{1}{16}$th of the ordinary breaking weight.

COMPARATIVE STRENGTH OF PILLARS OF IRON, STEEL AND WOOD—per square inch.

	No. of times length exceeds diameter.				
	10	20	24·6	30	40
	tons.	tons.	tons.	tons.	tons.
Northern Pine, dry ..	2 07	1·12	·77	·63	·39
Wrought Iron	15·55	14·18	13·05	12·37	10·48
Cast Iron	28·57	17·86	13·05	10·99	7·14
Strong Steel	44·00	33·33	28 47	23·53	16·67

It will thus be seen that in short columns cast iron is superior to wrought; but when the length exceeds about 26 times the diameter, the ends being fixed wrought iron has the advantage. Steel is much superior to either in both long and short columns.

Pillars of Stone, Etc.

Weight per foot super. at which fracture commences, the stone being laid on its quarry bed.

	Tons.
Granite, Aberdeen, blue	350
„ Dartmoor, best	325
„ Peterhead, blue..	300
„ „ grey	275
„ Kingstown, Dublin	300
„ Cornish, De Lank	280
„ „ Cheesewring	245
„ Guernsey	280
Slate	350
Limestone, Italian, white marble	350
„ compact Devonshire marble	300
„ magnesian, Roche Abbey	150
Sandstones, Craigleith, white	150
„ Red	140
„ York landings	130
„ Bramley Fall	120
Oolites, Portland, whit and base beds	90
„ Bath, Corsham	40
„ Bath box, best bed	40
„ Caen	40
Brick, fire, strong	120
„ „ Stourbridge, ordinary	90
„ stocks, strong, well burnt	60
„ place, good	15
„ „ inferior	10
Portland cement, pure, 3 months old	152
„ „ and sand, equal parts ..	100
„ „ „ 1 to 4	72
„ „ pure, 9 months old	240
„ „ and sand, equal parts ..	181

	Tons.
Portland cement and sand, 1 to 4	89
Chalk	5
Glass (annealed)	600

PIERS OF BRICK, STONE, ETC.—height under 12 times least thickness.

	Tons.
Bricks, hard stocks, best quality, set in Portland cement and sand, 1 to 1, 3 months old	40
Ditto, ordinary, well-burnt London stocks, ditto, ditto	30
Ditto, hard stocks, Roman cement and sand, 1 to 1 ditto	28
Ditto, ditto, Lias lime and sand, 1 to 2, 6 months old	24
Ditto, ditto, grey chalk, lime and sand, 1 to 2, ditto	12
Rubble masonry, flat bedded stones, Lias lime and sand, 1 to 2, 6 months old	40
Ditto, irregularly shaped stones, and ditto	15
Concrete in foundations, 1 Portland cement, and 5 of gravel and 1 of sand, 3 months old	40
Ditto, ditto, 1 blue Lias, and ditto, ditto, in moist ground	20

The *crushing* weight of stone is considerably more than that which causes it to fracture, being nearly double in the case of granite and most other stones.

Pillars or supports of stone or brick should, as a rule, be limited in height to 12 times their least thickness at the base to obtain their full strength; when longer, there is a considerable falling off in the load they will carry. A height of 24 times the thickness reduces the strength from 10 to 7;

when increased to 30 times, it is reduced to one-half; and when increased to 40 times, it is reduced to one third.

In practice, a dead load, the resultant of which passes through the axis of the pillar, should not, as a rule, exceed *one-fifth* of the weight at which fracture *commences*. This must be reduced in cases of a live load, or of one unequally distributed; and in no case should the safe load be reckoned at more than *one-tenth* of that which would crush the pillar.

In the author's practice as a consulting surveyor to the War Department, he adopted 5 tons per foot super. as a safe limit against crushing for best stock brickwork in Portland cement mortar with sand 1 to 2, although he has known cases in which brickwork in Portland cement safely withstood a pressure of 10 tons per foot super. If built with Lias lime mortar he adopted 3 tons per foot super.; and if with grey chalk lime mortar 1½ tons per foot super.; as it had to be remembered that the loads were to be sustained while the work was green. In all cases the joints of the brickwork were supposed to be flushed up solid with the mortar.

The factor of safety for concrete in foundations, if the ground is sufficiently solid to give it lateral support, and there is no danger of cross breaking, may be taken at *one-half* of the load that would cause fracture to commence.

Kirkaldy recommends thin pieces of pine or fir for the joints of stone pillars instead of lead, which causes a considerable reduction in the strength of the pillar, owing to the lateral pressure induced by the lead while endeavouring to spread itself outwards. Thin cardboard has also been suggested as preferable to either pine or fir.

ROOFS.

WOOD.

$$\left.\begin{array}{l} a = \text{Area of section} \\ b = \text{Breadth} \\ d = \text{Depth} \end{array}\right\} \text{in inches.}$$

$$\left.\begin{array}{l} \text{L} = \text{Length of piece} \\ \text{S} = \text{Span of roof} \end{array}\right\} \text{in feet.}$$

Pitch 27° to 45°.

King Post.

$a = \text{S}^2 \times 0 \cdot 03$ for pine, or by $0 \cdot 033$ for oak.

$$b = \frac{a}{d} \qquad d = \frac{a}{b}$$

Queen Post.

$a = \text{P}^2 \times 0 \cdot 135$ pine, or $0 \cdot 16$ oak.

P being the length in feet of that part of tie beam supported by the queen post (usually half the span).

Tie Beam.

$$d = \frac{\text{L}'}{\sqrt[3]{b}} \times 1 \cdot 47 \text{ pine, or } 1 \cdot 52 \text{ oak,}$$

L′ being the length in feet of the longest unsupported part.

Principal Rafters.

When there is a king post.

$$b\,d = \frac{\text{S}^2\,\text{T}}{50\,\text{R}} = \text{sectional area in square inches.}$$

When two queen posts,

$$b\,d = \frac{S^2\,T}{40\,R}$$

When four queen posts,

$$b\,d = \frac{S^2\,T}{38\,R}$$

T being the distance apart of the trusses, and R the rise of the roof, both in feet.

NOTE.—When principal rafters have to support a transverse load, as in the case of intermediate purlins, their strength should be calculated accordingly.

STRAINING BEAM.

Let its depth be to its thickness as 10 to 7, or as near to this proportion as possible.

$$d = \sqrt{L\,S^{\frac{1}{2}}} \times 0 \cdot 9 \text{ pine.}$$
$$b = 0 \cdot 7\,d.$$

STRUTS AND BRACES.

$$d = \sqrt{L\,P^{\frac{1}{2}}} \times 0 \cdot 8 \text{ pine.}$$
$$b = 0 \cdot 6\,d.$$

P being the length in feet of that part of the principal rafter supported by the strut L.

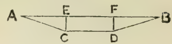
PURLINS.

$$d = \sqrt[4]{L^3\,C} \text{ pine, or } \times \text{ by } 1 \cdot 04 \text{ for oak.}$$
$$b = 0 \cdot 6\,d.$$

C being the distance in feet that the purlins are apart.

When the purlins are trussed with iron, as sketch,

Take depth E C = $\frac{1}{12}$th span.
E F = $\frac{1}{3}$rd ditto.



Then if W = weight of purlin and its load in cwts., and d = diameter of wrought-iron rod in inches, we have for the part C D,

$$d = \sqrt{W} \times 0 \cdot 13.$$

For parts A C and B D,

$$d = \sqrt{W} \times 0 \cdot 15.$$

The part A B should be nearly square, and the dimensions calculated as for a beam equal in length to the longest unsupported part, the load due to that part = $\frac{W}{3}$ in sketch.

When only one stay in the middle, and the depth of the truss = $\frac{\text{Span}}{12}$

$$d = \sqrt{W} \times 0 \cdot 14.$$

The stays E C and F D should be treated as pillars supporting $\frac{W}{3}$, as in sketch, or $\frac{W}{2}$ when there is a single stay in the middle.

For trussed beams of other proportions, see Art. on Transverse Strength.

Common Rafters.

$$d = \frac{L}{\sqrt[3]{b}} \times 0{\cdot}72 \text{ pine, or } 0{\cdot}74 \text{ oak.}$$

Two inches is the usual thickness for common rafters, in which case

$$d = {\cdot}571 \text{ L for pine.}$$

The formulæ given in some modern text-books omit the effect of the sun's rays in causing the upper edge of purlins, rafters and other timbers next the slates to shrink, and consequently to sag in the middle. Tredgold, guided by experience, adapted his rules to give extra depth accordingly.

Iron Straps to Wood Roofs.

When longest unsupported part of tie beam

= 10 feet,	strap should be	$1'' \times \frac{3}{16}''$
= 15	,, ,,	$1 \times \frac{1}{4}$
= 20	,, ,,	$2 \times \frac{1}{4}$

The straps at the feet of the principal rafters may be of the same section as that for supporting the tie beam.

Wooden Ribs for Domes.

The ribs for domes formed on the principle of De Lorme are usually in two thicknesses, each breaking joint with the other, the scantling of each thickness should be—

			in. in.
For domes of	24	feet diameter	8×1
,,	36	,,	$10 \times 1\frac{1}{2}$
,,	60	,,	13×2
,,	90	,,	$13 \times 2\frac{1}{2}$
,,	108	,,	13×3

Note.—The ribs are usually placed about 2 feet apart at the base, and the rafters, which should be laid horizontally, are notched to the back, with similar pieces on the inside, for the purpose of stiffening the ribs and to receive the boarding.

Table of Scantlings—Wood Roofs.

Span in feet.	Tie Beam.	King Post.	Queen Posts.	Small Queens.	Principal Rafters.	Straining Beam.	Braces.	Purlins.	Common Rafters.
	in. in.	in. in.	in. in.	in. in.	in. in.	in. in.	in. in.	in. in.	in. in.
20	9½ × 4	4 × 3	—	—	4 × 4	—	3½ × 2	8 × 4¾	3½ × 2
22	9½ × 5	5 × 3	—	—	5 × 3½	—	3¾ × 2¼	8¼ × 5	3¾ × 2
24	10½ × 5	5 × 3½	—	—	5 × 4	—	4 × 2½	8½ × 5	4 × 2
26	11½ × 5	5 × 4	—	—	5 × 4¼	—	4¼ × 2½	8¾ × 5	4¼ × 2
28	11½ × 6	6 × 4	—	—	6 × 3½	—	4½ × 2¾	8¾ × 5¼	4½ × 2
30	12 × 6	6 × 4½	—	—	6 × 4	—	4¾ × 3	9 × 5½	4¾ × 2
32	10 × 4½	—	4½ × 4	—	4½ × 6¾	6¾ × 4½	3¾ × 2¼	8 × 4¾	3½ × 2
34	10 × 5	—	5 × 3½	—	5 × 6½	6¾ × 5	4 × 2½	8¼ × 5	3¾ × 2
36	10½ × 5	—	5 × 4	—	5 × 6¾	7 × 5	4¼ × 2½	8½ × 5	4 × 2
38	10 × 6	—	6 × 3¾	—	6 × 6	7¼ × 6	4½ × 2½	8½ × 5	4 × 2
40	11 × 6	—	6 × 4	—	6 × 6½	8 × 6	4½ × 2½	8½ × 5	4¼ × 2
42	11½ × 6	—	6 × 4½	—	6 × 6¾	8¼ × 6	4½ × 2¾	8¾ × 5¼	4½ × 2
44	12 × 6	—	6 × 5	—	6 × 7	8½ × 6	4½ × 3	9 × 5	4¾ × 2
46	12½ × 6	—	6 × 5½	—	6 × 7¼	9 × 6	4¾ × 3	9 × 5½	5 × 2
48	11½ × 6	—	6 × 5¾	6 × 2¼	6 × 8	8¼ × 6	4½ × 2¾	8½ × 5	4 × 2
50	12 × 6	—	6 × 6¼	6 × 2½	6 × 8½	8½ × 6	4½ × 2¾	8¾ × 5	4¼ × 2
52	12 × 6½	—	6 × 6¾	6 × 2¾	6 × 8¾	8¾ × 6	4¾ × 2¾	8¾ × 5¼	4¼ × 2
54	12 × 7	—	7 × 6¼	7 × 2¼	7 × 7¾	9 × 6	4¾ × 2¾	8¾ × 5¼	4½ × 2
56	12 × 8	—	7 × 6¾	7 × 2½	7 × 8	9¼ × 6	5 × 2¾	8¾ × 5¼	4½ × 2
58	12 × 8½	—	7 × 7¼	7 × 2¾	7 × 8¼	9½ × 7	5 × 2¾	9 × 5¼	4¾ × 2
60	12 × 9	—	7½ × 7	7 × 3	7½ × 8	10 × 7	5 × 3	9 × 5½	4¾ × 2

Trusses, 10 feet apart; Pitch, 27°; Covering, Slate; Timber, Northern Pine.

Common Rafters.

12 inches apart from centre to centre.

Bearing in feet.	Breadth in inches.				
	1¾	2	2¼	2½	3
	Depth in inches.	Depth in inches.	Depth in inches.	Depth in inches.	Depth in inches.
5	3	2⅞	2¾		
8	4¾	4⅝	4⅜	4¼	4
10	6	5¾	5½	5⅜	5
12	7	6¾	6½	6⅜	6
14	8¼	8	7¾	7½	7
16	9½	9¼	8¾	8½	8
18	10½	10¼	10	9½	9
20	11¾	11½	11	10½	10

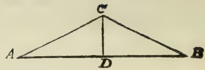
Purlins.

Of Northern Pine. Covering, Slate.

Bearing in feet.	Distance apart in feet.							
	6		7		8		9	
	Depth	Breadth	Depth	Breadth	Depth	Breadth	Depth	Breadth
6	6 ″ ×	3½″	6½″ ×	3¾″	6½″ ×	4 ″	6¾″ ×	4¼″
7	6¾ ×	4	7 ×	4¼	7¼ ×	4⅓	7½ ×	4½
8	7½ ×	4½	7¾ ×	4¾	8 ×	4¾	8½ ×	5
9	8½ ×	5	8½ ×	5¼	8¾ ×	5¼	9 ×	5½
10	8¾ ×	5¼	9¼ ×	5½	9½ ×	5¾	9¾ ×	5¾
11	9½ ×	5¾	9¾ ×	5¾	10¼ ×	6	10½ ×	6¼
12	10 ×	6	10½ ×	6¼	10¾ ×	6½	11¼ ×	6¾
13	10¾ ×	6½	11¼ ×	6¾	11½ ×	7	12 ×	7¼
14	11½ ×	6¾	11¾ ×	7	12¼ ×	7⅓	12½ ×	7½

Iron Roofs.

To find the stress on a simple truss,



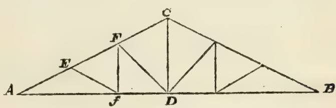
Let S = The half span A D.
R = The rise C D.
H = The tension on the tie rod.
T = The thrust along the rafter A C.
W = The gross weight of truss and its load.

Then,

$$H = \frac{W\,S}{4\,R}$$

$$T = \sqrt{H^2 + \frac{W^2}{16}} = \frac{W}{4}\sqrt{\frac{S^2}{R^2} + 1}$$

There is no stress on the king bolt C D of the simple truss when the tie rod is horizontal, except that arising from the tendency of the tie rod to sag in the middle



When the roof is trussed at one or more points on each side of the ridge, as at E and F,

Let H and T equal the tension on the tie rod and the thrust on the rafter as for a simple truss, and

N = the number of divisions of the rafter formed by the secondary trusses, as C F, F E, and E A = 3 in the diagram.

The stress on the tie rod
at the middle point $D = H$

Ditto, on part $f\,D = H\left(1 + \frac{1}{N}\right)$

Ditto, on part $A\,f = H\left(1 + \frac{2}{N}\right)$

And so on for any number of parts N, into which the rafter may be divided.

The thrust on the part
of the rafter $F\,C = T$

Ditto, on part $E\,F = T\left(1 + \frac{1}{N}\right)$

Ditto, on part $A\,E = T\left(1 + \frac{2}{N}\right)$

The weight suspended by a king bolt, C D,

$$= \frac{W}{2}\left(1 - \frac{1}{N}\right)$$

or by any other bolt, F f

$$= W\,\frac{N - m - 1}{4\,N}$$

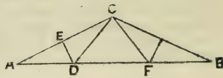
m being the number of divisions on the rafter distant from the ridge.

The stress on each strut F D and E f,

$$= \frac{W}{4\,N}\sqrt{\frac{S^2}{R^2} + (N - m)^2}$$

The stresses will all be in terms of W, which may be taken in lbs., cwts., or tons—and the proportions of the several parts may be calculated to resist those stresses according to the rules previously given for struts and ties.

For trusses, as sketch,



L = Length A C of rafter.
M = „ E D of strut.
N = „ A D or D C.
H = Tension on D F.
H′ = „ A D.
H″ = „ C D.
Q = Compression on E D.
T = „ A E of rafter.
T′ = „ C E „

R, S, and W = rise, half span, and load, as before. Then

$$H = \frac{W S}{4 R}$$

$$Q = \frac{W S}{4 L}$$

$$H'' = Q \frac{N}{2 M}$$

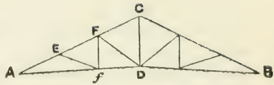
$$H' = H + H''$$

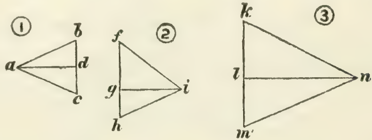
$$T = \sqrt{H'^2 + \frac{9}{64} W^2}$$

$$T' = T - \sqrt{\frac{W^2}{16} - Q^2}$$

When the tie rod is cambered, the stresses are increased. They may be obtained more readily by the graphic method, such as that derived from the parallelogram of forces, or the method of closed polygons suggested by Rankine and Clark Maxwell, as follows:

To find the stresses in the truss A.





Divide the load on each side of the truss into twice as many parts as there are divisions in the rafter ($2 \times 3 = 6$ in sketch). One of the parts will be supported at A, two at E, two at F, and two at C (i.e. one for each side of the roof).

To find the stresses take $b\,c$, diagram No. 1, equal to the load at E, draw $b\,a$ and $c\,a$ parallel to the rafter E A and strut E f respectively, and from a draw $a\,d$ parallel to the tie rod A f; the lengths of each of these lines will give the stress due to the load at E, on the parts of the roof to which they are parallel. To find the stress due to the load at F, construct diagram No. 2, $f\,h$ representing the load at F = (2 parts), *plus* the pull on the queen bolt F $f = d\,c$ due to the strut E f; then $f\,i$ drawn parallel to the strut F D, $h\,i$ to rafter F E, and $g\,i$ to the tie rod f D, will give the stress on those parts due to the load and pull at F. Next construct diagram No. 3, taking $k\,m$ to represent the load at C = (2 parts), *plus* the pull from the strut F D on each side of the king bolt = twice $f\,g$, then the lines $k\,n$ and $m\,n$ will represent respectively the stress on the rafter at each side of the ridge, and $l\,n$ that on the tie rod at the centre D.

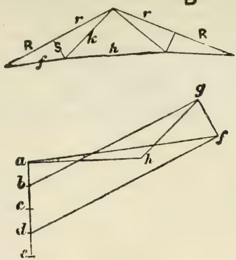
Then the total stress on the tie rod between f and D will be represented by $l\,n + g\,i$, and on the part beween f and A will be represented by $l\,n + g\,i + a\,d$.

The stresses on the rafter from C to F will be represented by $k\,n$ or $m\,n$, from F to E by $k\,n + h\,i$, and from E to A by $k\,n + h\,i + b\,a$. Twice $f\,g$ will represent the tension on the king bolt C D, and $d\,c$ the tension on the queen bolt F f. The thrust on the strut F D will be represented by $f\,i$, and that on E f by $a\,c$.

In a similar manner can be found the stresses, whatever number of king and queen bolts there may be.

The stresses in the truss B may be worked out in a very simple manner by the method suggested by Mr. Clark Maxwell, as follows:

B



Divide the load on each side of the truss, as before (= 4 parts in sketch). Take the vertical line $a\ e$ to represent the reaction of the pier = half the load of the whole truss, divide it into 4 equal parts to represent the divisions of the load on each rafter, the lower part $d\ e$ being taken to represent the force due to the foot of the rafter resting on the pier, and acting in an opposite direction to the reaction caused by the truss.

The load on the strut at the middle of the rafter being represented by $b\ d$, the line $d\ f$ drawn parallel to the rafter meeting the line $a\ f$ drawn parallel to the tie rod f will represent the thrust on the rafter at R, and $a\ f$ the tension on the tie rod f; the lengths of the lines $b\ g$ parallel to the rafter r, and $g\ f$ parallel to the strut S, will give the stresses in each of these parts.

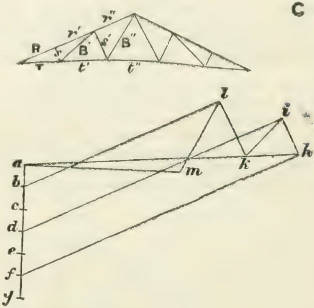
The intersection of the line $a\ h$ drawn parallel to the horizontal portion h of the tie rod with $g\ h$ drawn parallel to the tension rod k, will give the stresses on the parts.

To find the stresses on a truss similar to C.

Draw a vertical line $a\ g$ to represent the load on one side of the roof, and divide it into twice the number of parts (= 6 in sketch) that there are divisions in the rafter. Take $f\ g$ to

represent the vertical stress at the foot of the rafter R, and $d\,f$ to represent the load over the strut S; draw $f\,h$ parallel to the rafter, and $a\,h$ parallel to the tie rod, and these lengths from the point of intersection h to the vertical line $a\,g$ will give the thrust on the rafter at R, and the tension on the tie

C



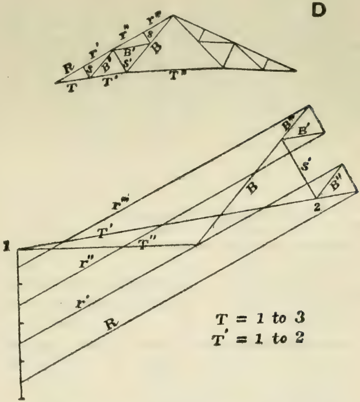
rod at T; $d\,i$ drawn in the same manner parallel to the rafter at r', and $h\,i$ parallel to the strut S, will give the stresses on r' and S respectively. $i\,k$ drawn parallel to the brace B until it meets $a\,h$, will give the stress on B, and $k\,l$ drawn parallel to S′ until it intersects $b\,l$ drawn parallel to the rafter at r'' will give the stress on the strut S′, $l\,b$ being the thrust on the part of the rafter r''. The stress on the tie rod at t' will be represented by $a\,k$, and that on the horizontal part t'' by $a\,m$, found by drawing a horizontal line from a until it meets $l\,m$, drawn parallel to B″, of which it represents the stress.

In the same manner may be found the stresses when the rafters are in any other number of divisions.

The stresses on the truss D may be found in a similar manner, as shown by the following diagrams.

NOTE.—Where wind exerts a downward pressure on a roof, say of high pitch normal to its sloping surface, the effect on the various corresponding members of the truss on each side is unequal, and depends on

D



$T = 1 \text{ to } 3$
$T' = 1 \text{ to } 2$

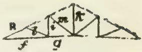
which side the truss is fixed on the wall, and also on the direction of the wind. Such cases arise in very high pitched roofs similar to those of large railway sheds. Special calculations for the effect of the wind should be made in such cases, as shown in most of the Academical Text-Books on the subject. On the roofs here contemplated the wind seldom exerts any pressure at all, owing to its deflection upwards by the escaping wind blown against the vertical sides of the building. No case has been known in this country of a roof being crushed in from the force exerted by wind; instead of which, roofs have sometimes been blown off. Hence, in order to simplify the calculation, the load due to the weight of the roof, snow, &c., with an addition of from 20 lbs. to 25 lbs. per foot super., is taken as if it acted vertically, experience having proved that the parts so calculated are sufficient to resist the effects of any wind to which ordinary roofs are liable in the United Kingdom. The margin allowed by the factor of safety is considered sufficient to resist the effects of an exceptional gust of wind.

The distance apart of the trusses can be adjusted according as the weight of the roof covering differs from that assumed in the tables.

The following Tables show the minimum proportions for iron trusses, usually adopted in practice when the roofs are covered with countess or similar slates.

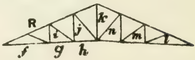
In fixing iron roofs, care should be taken to have the connections properly forged, and the bolts and keys of sufficient strength.

Rise = $\frac{1}{4}$ span.
Camber of tie rod = $\frac{1}{30}$ span.
Distance apart of trusses = 8 feet.



Span.	Tie Rod. Diameter.		Bolts. Diameter.		Struts. Sectional Area.		T Rafters.
	f	g	i	k	l	m	R
feet.	"	"	"	"	"	"	" " "
20	$\frac{15}{16}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	0·8	0·9	$3\frac{1}{4} \times 2\frac{1}{2} \times \frac{7}{16}$
22	$\frac{15}{16}$	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	0·9	1·0	$3\frac{1}{2} \times 2\frac{1}{2} \times \frac{7}{16}$
24	1	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{11}{16}$	1·0	1·1	$3\frac{1}{2} \times 2\frac{3}{4} \times \frac{7}{16}$
26	$1\frac{1}{16}$	$\frac{15}{16}$	$\frac{1}{2}$	$\frac{11}{16}$	1·1	1·2	$3\frac{3}{4} \times 2\frac{3}{4} \times \frac{7}{16}$
28	$1\frac{1}{16}$	1	$\frac{1}{2}$	$\frac{11}{16}$	1·2	1·3	$4 \times 2\frac{3}{4} \times \frac{7}{16}$
30	$1\frac{1}{8}$	1	$\frac{1}{2}$	$\frac{3}{4}$	1·2	1·4	$4 \times 3 \times \frac{1}{2}$
32	$1\frac{3}{16}$	$1\frac{1}{16}$	$\frac{1}{2}$	$\frac{3}{4}$	1·3	1·5	$4\frac{1}{4} \times 3 \times \frac{1}{2}$
34	$1\frac{3}{16}$	$1\frac{1}{16}$	$\frac{1}{2}$	$\frac{13}{16}$	1·3	1·5	$4\frac{1}{2} \times 3 \times \frac{1}{2}$
36	$1\frac{1}{4}$	$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{13}{16}$	1·4	1·6	$4\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$
38	$1\frac{1}{4}$	$1\frac{1}{8}$	$\frac{1}{2}$	$\frac{13}{16}$	1·5	1·7	$4\frac{3}{4} \times 3\frac{1}{2} \times \frac{1}{2}$
40	$1\frac{5}{16}$	$1\frac{3}{16}$	$\frac{1}{2}$	$\frac{13}{16}$	1·5	1·7	$4\frac{3}{4} \times 3\frac{1}{2} \times \frac{5}{8}$

Rise = $\frac{1}{4}$ span.
Camber of tie rod = $\frac{1}{30}$ span.
Distance apart of trusses = 10 feet.

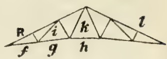


Span.	Tie Rod. Diameter.			Bolts. Diameter.			Struts. Sectional Area.			T Rafters.
	f	g	h	i	j	k	l	m	n	R
feet.	"	"	"	"	"	"	"	"	"	" " "
40	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{9}{16}$	1	1·4	1·6	2·1	$4\frac{3}{4} \times 3\frac{1}{2} \times \frac{5}{8}$
42	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{9}{16}$	1	1·4	1·7	2·2	$5 \times 3\frac{1}{2} \times \frac{5}{8}$
44	$1\frac{9}{16}$	$1\frac{7}{16}$	$1\frac{5}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$1\frac{1}{16}$	1·5	1·8	2·3	$5 \times 3\frac{3}{4} \times \frac{5}{8}$
46	$1\frac{9}{16}$	$1\frac{7}{16}$	$1\frac{5}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$1\frac{1}{16}$	1·6	1·9	2·4	$5\frac{1}{4} \times 3\frac{3}{4} \times \frac{5}{8}$
48	$1\frac{5}{8}$	$1\frac{1}{2}$	$1\frac{3}{8}$	$\frac{1}{2}$	$\frac{9}{16}$	$1\frac{1}{16}$	1·6	2·0	2·5	$5\frac{1}{2} \times 3\frac{3}{4} \times \frac{5}{8}$
50	$1\frac{5}{8}$	$1\frac{1}{2}$	$1\frac{3}{8}$	$\frac{1}{2}$	$\frac{9}{16}$	$1\frac{1}{8}$	1·7	2·1	2·6	$5\frac{3}{4} \times 3\frac{3}{4} \times \frac{5}{8}$
52	$1\frac{11}{16}$	$1\frac{9}{16}$	$1\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$1\frac{1}{8}$	1·8	2·2	2·7	$5\frac{3}{4} \times 4 \times \frac{5}{8}$
54	$1\frac{11}{16}$	$1\frac{9}{16}$	$1\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$1\frac{1}{8}$	1·9	2·3	2·8	$6 \times 4 \times \frac{5}{8}$
56	$1\frac{3}{4}$	$1\frac{5}{8}$	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$1\frac{3}{16}$	2·0	2·4	2·9	$6 \times 4\frac{1}{4} \times \frac{5}{8}$
58	$1\frac{3}{4}$	$1\frac{5}{8}$	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$1\frac{3}{16}$	2·1	2·5	3·0	$6 \times 4\frac{1}{2} \times \frac{5}{8}$
60	$1\frac{13}{16}$	$1\frac{11}{16}$	$1\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$1\frac{3}{16}$	2·2	2·6	3·2	$6 \times 4\frac{1}{2} \times \frac{3}{4}$

Rise = $\frac{1}{4}$ span.
Camber of tie rod = $\frac{1}{30}$ span.
Distance apart of trusses = 6 feet.

Span.	Tension Rods (Diameter).			Strut.	T Rafters.
	f	h	k	Area.	R
feet.	$''$	$''$	$''$	sq. inches.	$'' \quad '' \quad ''$
20	$\frac{13}{16}$	$\frac{5}{8}$	$\frac{1}{2}$	·7	$3 \times 2 \times \frac{3}{8}$
22	$\frac{13}{16}$	$\frac{5}{8}$	$\frac{9}{16}$	·8	$3 \times 2\frac{1}{4} \times \frac{3}{8}$
24	$\frac{7}{8}$	$\frac{11}{16}$	$\frac{9}{16}$	·9	$3 \times 2\frac{1}{2} \times \frac{3}{8}$
26	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{5}{8}$	·9	$3\frac{1}{4} \times 2\frac{1}{2} \times \frac{3}{8}$
28	$\frac{15}{16}$	$\frac{3}{4}$	$\frac{5}{8}$	1·0	$3\frac{1}{4} \times 2\frac{1}{2} \times \frac{7}{16}$
30	1	$\frac{3}{4}$	$\frac{11}{16}$	1·1	$3\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{2}$
32	1	$\frac{3}{4}$	$\frac{11}{16}$	1·1	$3\frac{1}{2} \times 3 \times \frac{1}{2}$
34	$1\frac{1}{16}$	$\frac{13}{16}$	$\frac{11}{16}$	1·2	$4 \times 3 \times \frac{1}{2}$
36	$1\frac{1}{16}$	$\frac{13}{16}$	$\frac{3}{4}$	1·3	$4 \times 3\frac{1}{4} \times \frac{1}{2}$
38	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	1·4	$4\frac{1}{4} \times 3\frac{1}{4} \times \frac{1}{2}$
40	$1\frac{1}{8}$	$\frac{7}{8}$	$\frac{3}{4}$	1·4	$4\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$

Rise = $\frac{1}{4}$ span.
Camber of tie rod = $\frac{1}{30}$ span.
Distance apart of trusses = 8 ft.



Span.	Tie Rod.			Bolts.		Struts. Sectional Area.		T Rafters.
	f	g	h	i	k	l	m	R
feet.	$''$	$''$	$''$	$''$	$''$	$' \; ''$	$' \; ''$	$'' \quad '' \quad ''$
20	$\frac{15}{16}$	$\frac{13}{16}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	0·6	0·8	$3\frac{1}{4} \times 2\frac{1}{2} \times \frac{7}{16}$
22	1	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{9}{16}$	0 6	0·9	$3\frac{1}{2} \times 2\frac{1}{2} \times \frac{7}{16}$
24	1	$\frac{15}{16}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	0·7	1·0	$3\frac{1}{2} \times 2\frac{3}{4} \times \frac{7}{16}$
26	$1\frac{1}{16}$	$\frac{15}{16}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	0·8	1·1	$3\frac{3}{4} \times 2\frac{3}{4} \times \frac{7}{16}$
28	$1\frac{1}{8}$	1	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	0·9	1·2	$4 \times 2\frac{3}{4} \times \frac{7}{16}$
30	$1\frac{1}{8}$	1	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	1·0	1·3	$4 \times 3 \times \frac{1}{2}$
32	$1\frac{3}{16}$	$1\frac{1}{16}$	$\frac{7}{8}$	$\frac{9}{16}$	$\frac{5}{8}$	1·1	1·4	$4\frac{1}{4} \times 3 \times \frac{1}{2}$
34	$1\frac{3}{16}$	$1\frac{1}{16}$	$\frac{15}{16}$	$\frac{9}{16}$	$\frac{11}{16}$	1·2	1·5	$4\frac{1}{2} \times 3 \times \frac{1}{2}$
36	$1\frac{1}{4}$	$1\frac{1}{8}$	$\frac{15}{16}$	$\frac{9}{16}$	$\frac{11}{16}$	1·3	1·6	$4\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$
33	$1\frac{5}{16}$	$1\frac{3}{16}$	1	$\frac{9}{16}$	$\frac{11}{16}$	1·4	1·7	$4\frac{3}{4} \times 3\frac{1}{2} \times \frac{1}{2}$
40	$1\frac{5}{16}$	$1\frac{3}{16}$	1	$\frac{5}{8}$	$\frac{3}{4}$	1·5	1·7	$4\frac{3}{4} \times 3\frac{1}{2} \times \frac{5}{8}$

PITCH OF ROOFS (Minimum).

Covering.	Angle with Horizon.	Ratio of Rise to Span.
	° ′	
Tin	5 43	$\frac{1}{20}$
Lead	"	"
Zinc	"	"
Copper	7 36	$\frac{1}{15}$
Corrugated Iron	11 18	$\frac{1}{10}$
Asphalted Felt	18 26	$\frac{1}{6}$
Slates, Queens	22 0	$\frac{1}{5}$
" Ordinary	26 33	$\frac{1}{4}$
Thin slabs of stone	"	"
Pantiles	33 40	$\frac{1}{3}$
Plain tiles	45 0	$\frac{1}{2}$
Thatch	"	"

In localities exposed to much wind and rain the pitch of slates should not be less than $\frac{1}{3}$rd of the span.

WEIGHT OF ROOFS.

		A	B
Iron Trusses, each—		lbs.	lbs.
20 feet span	=	270	220
30 "	=	620	480
40 "	=	1135	840
50 "	=	1890	
60 "	=	3000	
Wood Trusses, each—			
King post, 20 feet span	=		390
" 30 "	=		1020
Queen post, 40 feet span	=		1460
" 50 "	=		2230
" 60 "	=		3640

	lbs. per foot super.
Common rafters and purlins (wood trusses)	7
" " (iron ")	6
$\frac{3}{4}$-inch deal boarding	2·5

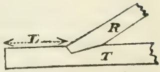
	lbs. per foot super.
1-inch deal boarding	3·4
1¼ " "	4·25
Battens 3 × ¾-laid 7½ gauge	1·43
Battens 3 × ¾-laid 8½ gauge	1·32
" " 10½ "	1·11
Asphalted felt	0·5
Zinc, laid with rolls, 12 gauge	1·5
" " 14 "	1·7
" " 16 "	1·9
Lead and copper according to weight per foot, adding $\frac{1}{10}$th for seams and laps. Rolls to be taken in addition when used.	
Corrugated iron, galvanised, 20 S W gauge, with 5″ corrugations (measured over all)	2·00
Ditto, 18 ditto, ditto	2·60
Slates, 3″ lap, all sizes, except Duchesses, Rags or Queens, including nails (but not battens)	8·5
Duchesses	9·0
Rags and Queens	12·0
Tiles, plain, 10½″ × 6″ × ½″ including mortar for pointing, 8″ gauge	16·0
Ditto, ditto, 7″ gauge	18·5
" 6 "	21·0
Tiles, pan, pointed with mortar, average, including absorbed rain	11·0
Thatch of straw	7·0
Ceiling, including joists, 10 feet bearing, and lath and plaster	12·0
Wind, allow for vertical effect on roof, ¼ pitch	20·0
Ditto, ditto, ⅓ pitch	23·0
" ½ pitch	25·0
Snow, according to climate.	3 to 10·0

Roof Drainage.

Rain-water or down pipes should have a bore or internal area of at least 1 square inch for every 60 super. feet of roof surface in temperate climates, and about 35 feet super. in tropical climates. They should be placed not more than 20 feet apart to

allow of sufficient fall in the eaves gutters, which should be increased in size if the down pipes are further apart. Eaves gutters should never be less in width than twice the internal diameter of the down pipe, more would be an advantage.

Resistance of the Ends of Tie Beams, &c., to Shearing from the Thrust of the Rafter.



Let b = The breadth of the beam in inches.
Let h = The horizontal thrust of rafter in lbs.
Let l = The length of tie beam from the end to the foot of the rafter in inches.

For oak $l = \frac{h}{500\,b}$

For pine $l = \frac{h}{130\,b}$

This part, however, is usually secured by a wrought-iron strap, which should be of a section proportionate to the thrust of the rafter.

Scarfed Joints in Tie Beams, &c. (Tredgold).

The proportion of the length of scarf to depth of beam.

	Without Bolts.	With Bolts.	With Bolts and Indents.
Oak, ash, elm, &c.	6 D	3 D	2 D
Pine	12 D	6 D	4 D

NOTE.—With soft woods, such as pine and fir, iron bolts should always be used to prevent splitting.

WATER SUPPLY.

	Gal.
In temperate climates, for each man, woman, and child, allow for house supply, per day ..	20
In tropical climates, allow	25
Soldiers require for all purposes, per man per day	15
Hospitals require *one-third* more water per man than dwelling houses.	
Allow per day for each horse (food and drink $\frac{2}{3}$, washing $\frac{1}{3}$rd)	15
An elephant will consume per day about.. ..	25
A camel ,, ,, ...	10
An ox or cow ,, ,, ...	8
Mule, donkey, or pony ,, ...	6
Sheep or pig ,, ,, ...	1

Cavalry horses are usually allowed 8 gallons of water, and artillery horses 10 gallons per day, which include washing the horses and carriages.

Allow per day for cleaning each two-wheeled carriage	8
Ditto four-wheeled cart or waggon	12
Ditto four-wheeled coach or carriage	20

A large bath requires from 40 to 50 gallons.

A shower bath from 3 to 6 gallons.

A water-closet, each flushing from 2 to 3 gallons.

In towns allow for each superficial yard for watering the streets per day during 120 days in the year $\frac{1}{3}$rd gallon.

In manufacturing towns an allowance of from 3 to 7 gallons should be made in addition to that required for domestic purposes.

As a general rule 30 gallons per head, which is

the supply to London on the intermittent system, will cover the requirements of most towns.

The *maximum* hourly demand of water for domestic purposes may become three times the *average* hourly demand.

If the source be rainfall, provide tankage for at least 120 days' supply. In tropical climates this should be increased according to fluctuations in the rainfall.

Service tanks should be capable of holding three days' supply.

Tanks or cisterns containing water for domestic use should not be exposed to the sun or placed where liable to contamination.

The available rainfall from roofs in England varies according to locality, being more in the western districts than in the eastern. It may, however, be roughly estimated for water supply at 18 inches per annum as an average.

The maximum hourly rainfall on roofs in England may be estimated at 1 inch, and in rare cases at $1\frac{1}{2}$ inch.

The loss from reservoirs by evaporation when exposed to the sun in the summer months, varies from $\frac{1}{6}$th to $\frac{1}{8}$th of an inch per day; and the average evaporation throughout the year varies from $\frac{1}{12}$th to $\frac{1}{16}$th of an inch per day.

A = Sectional area in feet.
d = Diameter of pipe in inches.
G = Supply in gallons per minute.
H = Head of water in feet.
L = Length of pipe in feet.
Q = Discharge in cubic feet per second.
V = Velocity in feet per second.

$R =$ The hydraulic radius or mean depth in feet

$$= \frac{\text{sectional area}}{\text{perimeter}} = \text{in pipes } \frac{\text{diam. in ft.}}{4}$$

$S =$ The sine of the inclination of the pipe,

$$\text{or } \frac{\text{total fall}}{\text{total length}}$$

Eytelwein's Formula.

Open channels, &c.

$$V = 95 \sqrt{R\,S}$$

$$Q = 95\,A \sqrt{R\,S}$$

Pipes.

$$V = 13 \cdot 7255 \sqrt{d\,S}$$

$$G = 28 \sqrt{d^5\,S}$$

$$H = \frac{G^2\,L}{784\,d^5}$$

$$d = \sqrt[5]{\frac{G^2\,L}{784\,H}}$$

$$L = \frac{784\,d^5\,H}{G^2}$$

Neville's Formula.

Open channels and pipes.

$$V = 140 \sqrt{R\,S} - 11 \sqrt[3]{R\,S}$$

$$Q = A\,V$$

$G = 2 \cdot 04\, d^2\, V =$ Supply in gallons per minute.

Eytelwein's formula, though most used by Engineers, gives correct results only when the velocity is about $1\frac{1}{2}$ foot per second, under-estimating the supply

with greater velocities and over-estimating it with lesser velocities; thus with a velocity of 20 feet per second, the deficiency in the formula is about 25 per cent., and with a velocity of 1 inch per second the excess is over 40 per cent.

Neville's formula is the most accurate for all velocities, although not so convenient to use.

In the formula, H represents merely the head required to overcome friction, and is therefore less than the actual head, a portion of which is required to maintain the velocity of the water in the pipe, to overcome the resistance at the orifice of entry from the reservoir, and the resistance due to bends, angles, &c., all of which require to be deducted from the total head to obtain the true value of H. These resistances or "losses of head" being dependent on the velocity of the water, the latter may be found in the first instance from the Tables, or by the formula, the actual or total head being used as an approximation. Any further degree of accuracy may be attained by repeating the operation and using the last corrected value of H to find a new velocity.

Head due to velocity.

$$H_v = \frac{V^2}{64\cdot4} = \cdot015528\,V^2.$$

Velocity in feet per sec.	Head in feet.	Velocity in feet per sec.	Head in feet.	Velocity in feet per sec	Head in feet.	Velocity in feet per sec.	Head in feet.
0·5	·0039	3·0	·1398	6·0	·559	11·0	1·879
0·75	·0087	3·25	·1640	6·5	·656	12·0	2·236
1·0	·0155	3·5	·1902	7 0	·761	13·0	2·624
1·25	·0243	3·75	·2184	7·5	·874	14·0	3·043
1·5	·0349	4·0	·2485	8·0	·994	15·0	3·494
1·75	·0476	4·25	·2805	8 5	1·122	16·0	3·975
2·0	·0621	4·5	·314	9·0	1·258	17·0	4·488
2·25	·0786	4·75	·350	9 5	1·401	18·0	5·031
2·5	·0971	5·0	·388	10 0	1·553	19·0	5·606
2·75	·1174	5·5	·470	10·5	1·712	20·0	6·211

Head due to orifice of entry.

$H_o = V^2 \times C$

$C =$ ·007849 for round orifices such as the end of a pipe.

$=$ ·000444 ditto when splayed or bell-mouthed.

$=$ ·014846 ditto when the pipe projects into the cistern (diameter uniform).

$=$ ·012077 square orifices flush with the face of the cistern.

TABLE FOR CIRCULAR ORIFICES.

Velocity in Feet per Second.	Head in Feet.			Velocity in Feet per Second.	Head in Feet.		
	Flush with Face of Cistern.	Flush and Bell-mouth'd.	Pro-jecting into Cistern.		Flush with Face of Cistern.	Flush and Bell-mouth'd.	Pro-jecting into Cistern.
1	·0078	·0004	·0148	6	·2826	·0160	·5345
2	·0314	·0018	·0594	7	·3846	·0218	·7275
3	·0706	0040	·1336	8	·5023	·0284	·9501
4	·1256	·0070	·2375	9	·6358	·0360	1·2025
5	·1962	·0111	·3712	10	·7849	·0444	1·4846

Head due to bends and elbows.

Circular Bends. When the radius of the axis of the bend is greater than 5 diameters of the pipe, the head (H_b) in feet due to its resistance may be taken as

$$H_b = \frac{V^2 \theta}{88489}$$

θ being the number of degrees in the bend.

When the radius of the bend is less than five diameters, Weisbach's formula is the most accurate, viz.

$$H_b = \frac{V^2 \theta}{11592} \times \left\{ ·131 + 1·847 \left(\frac{d}{2r} \right)^{\frac{7}{2}} \right\}$$

d being the internal diameter of the pipe, and *r* the radius of the axis of the bend, both in inches.

TABLE FOR CIRCULAR BENDS OF 90°.

$\frac{r}{d}$	Velocity in Feet per Second.									
	1	2	3	4	5	6	7	8	9	10
	Head in Feet.									
1	·0023	·0091	·0206	·0366	·0571	·0822	·1119	·1462	·1850	·2284
$1\frac{1}{4}$	·0016	·0064	·0144	·0256	·0399	·0575	·0783	·1022	·1294	·1598
$1\frac{1}{2}$	·0013	·0053	·0119	·0212	·0331	·0477	·0645	·0847	·1072	·1324
2	·0011	·0045	·0102	·0181	·0282	·0406	·0553	·0723	·0915	·1129
3	·0010	·0042	·0094	·0167	·0261	·0376	·0512	·0668	·0846	·1044
4	·0010	·0041	·0092	·0164	·0257	·0370	·0493	·0657	·0832	·1027
5	·0010	·0041	·0092	·0163	·0255	·0368	·0501	·0654	·0828	·1022
6	·0010	·0041	·0092	·0163	·0255	·0367	·0500	·0652	·0826	·1019

Elbows or Angles.

$$H_a = \frac{V^2}{64 \cdot 4} \times \left(\cdot 9457 \sin.^2 \frac{\phi}{2} + 2 \cdot 047 \sin.^4 \frac{\phi}{2} \right)$$

ϕ being the angle of deflection from the straight portion of the pipe.

For particular cases this formula may be simplified as follows:

$H_a = V^2 \times C.$

C =	·000109	when angle of def. =	10°
=	·000466	,,	20°
=	·001134	,,	30°
=	·002158	,,	40°
=	·003634	,,	50°
=	·005652	,,	60°
=	·008276	,,	70°
=	·011491	,,	80°
=	·015248	,,	90°

When the length of the pipe exceeds 1000 diameters, the heads due to velocity, orifice, and even bends unless very numerous, are in general so small compared with that due to the friction in the pipe, that they may be neglected except where great accuracy is required.

In the case of pipes which are vertical or nearly so, to obtain results equal to those given by the formula and Tables, there must be a sufficient head of water over the entrance to the pipe to produce the velocity of discharge, and to overcome the resistance at the orifice of entry.

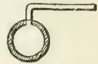
For incrustation allow $\frac{1}{6}$th of the diameter for pipes under 6 inches, and 1 inch for all pipes above 6 inches diameter.

Branch Pipes are calculated in the same manner as mains, the total head in the branch being the effective head in the main at the junction. When branch pipes are at right angles with the main, the velocity of the water in the latter is supposed to be lost as regards the branch. Therefore the head due to velocity as in the case of entry from the reservoir, must be deducted, also that due to the gurglitation (érogation) at the junction; the latter is usually taken as equal to about *twice* the head due to the velocity in the branch. Therefore the effective head will equal that in the main less *three* times the head due to the velocity in the branch.

When a branch pipe proceeds from the main at less than a right angle, a portion only of the velocity will be lost, the head due to the remainder, called the "velocity of approach," should be added if the full deduction be made, as in the case of branches at right angles.

Service Pipes should be calculated in the same

manner, but as they usually start vertically from the main or branch, and then bend as in sketch, the loss of head due to the bend and also to the vertical portion of the pipe must be deducted.



Cocks or Taps at the end of a service pipe cause very little diminution in the discharge, except in the case of a bib cock, where the obstruction would be equivalent to that of an ordinary bend.

From experiments by the author it would appear that contracting the area of the pipe at the outlet equal to one-half, reduces the discharge from 1 to ·962, and contracting it to one-fourth reduces it to ·700. The experiments of D'Aubuisson indicate even a less reduction in the discharge.

Branch pipes should be of such a capacity as to yield a sufficient supply of water in case of fires occurring.

Sudden enlargements or contractions in a pipe cause loss of head, and should therefore be avoided.

Pipes should not be laid above the line of "Hydraulic Inclination," i.e. the contour formed by the effective heads or height at which the water during its flow would stand in pipes raised vertically along the main pipe, otherwise an accumulation of air would take place in the parts that were above the line, and very much retard or prevent the flow, unless means were taken to permit its escape.

Overflow Pipes to Cisterns. The discharge from a trumpet mouth standing waste, according to Mr. Box, is

$$\text{Gallons per minute} = 8 \cdot 4\, d\, h^{\frac{3}{2}},$$

in which d is the diameter of the trumpet mouth, and h the head of water over the lip, measured from still water, both in inches.

This rule must be considered as approximate only, as the discharge will be influenced by the proportion which the trumpet mouth bears to the pipe on which it is fixed; if the head above the mouth be sufficient to produce the velocity of discharge, the rules for ordinary pipes may be used.

To prevent Oxidation and Deposits in Iron Pipes.—Thoroughly cleanse the pipes from dust, sand, and rust, heat to a temperature of about 500° Fahr., and immerse for a few minutes in a bath of melted coal-tar pitch. This operation answers best when performed immediately after the pipes are removed from the mould in which they were cast.

Another method sometimes adopted is to heat and maintain the pitch at a temperature of at least 300° Fahr., and immerse the pipe, which must be thoroughly clean, until the iron has attained the same temperature, which it usually does in about 30 to 40 minutes, according to the temperature of the atmosphere.

NOTE.—The pitch used is made from coal-tar, distilled until the naphtha has been removed; it should be about the consistency of wax; 6 per cent. of linseed oil, and sometimes a little resin, are added. Pitch which becomes hard and brittle when cold should be rejected.

It is found that after several pipes have been coated the contents of the bath become thick and brittle, in which case fresh pitch should be added, and occasionally the entire contents changed.

CYLINDRICAL PIPES.—Table showing the Velocity in Feet per Second, and the Supply in Gallons per Minute, for Long Pipes flowing full, calculated from the Formula $V = 140\sqrt{RS} - 11\sqrt[3]{RS}$.

Diameter of pipe in inches.	Head of Water divided by Length of Pipe.								Diameter of pipe in inches.
	$\frac{1}{1000}$		$\frac{1\cdot2}{1000}$		$\frac{1\cdot4}{1000}$		$\frac{1\cdot6}{1000}$		
	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	
$\frac{3}{8}$	·173	·05	·197	·06	·219	·06	·240	·07	$\frac{3}{8}$
$\frac{1}{2}$	·212	·11	·240	·12	·266	·14	·291	·15	$\frac{1}{2}$
$\frac{3}{4}$	·278	·32	·314	·36	·347	·40	·378	·43	$\frac{3}{4}$
1	·336	·69	·378	·77	·417	·85	·454	·93	1
$1\frac{1}{4}$	·388	1·24	·436	1·39	·481	1·53	·522	1·66	$1\frac{1}{4}$
$1\frac{1}{2}$	·436	2·00	·489	2·24	·538	2·47	·585	2·68	$1\frac{1}{2}$
$1\frac{3}{4}$	·481	3·00	·538	3·36	·592	3·70	·643	4·01	$1\frac{3}{4}$
2	·522	4·26	·585	4·77	·643	5·24	·697	5·69	2
$2\frac{1}{2}$	·600	7·64	·670	8·55	·736	9·38	·798	10·17	$2\frac{1}{2}$
3	·670	12·30	·749	13·74	·820	15·06	·889	16·33	3
4	·798	26·03	·889	29·03	·975	31·81	1·05	34·42	4
5	·911	46·48	1·02	51·84	1·11	56·68	1·20	61·30	5
6	1·02	74·64	1·13	82·99	1·24	90·82	1·34	98·15	6
7	1·11	111·09	1·24	123·61	1·35	135·20	1·46	146·06	7
8	1·20	156·92	1·34	174·49	1·46	190·77	1·58	206·03	8
9	1·29	212·71	1·43	236·43	1·56	258·40	1·69	278·87	9
10	1·37	279·16	1·52	310·11	1·66	338·81	1·79	365·79	10
11	1·45	356·95	1·61	396·45	1·75	433·06	1·89	467·34	11
12	1·52	446·66	1·69	495·95	1·84	541·92	1·99	584·37	12
15	1·73	793·27	1·92	880·20	2·09	960·70	2·26	1036·0	15
18	1·92	1267·5	2·13	1405·7	2·32	1533·5	2·50	1653·2	18
24	2·26	2652·2	2·50	2939·1	2·73	3204·4	2·94	3453·8	24
30	2·56	4698·8	2·83	5203·9	3·09	5671·2	3·33	5924·5	30

CYLINDRICAL PIPES—*continued.*

Diameter of pipe in inches.	Head of Water divided by Length of Pipe.								Diameter of pipe in inches.
	1·8/1000		2/1000		2·25/1000		2·5/1000		
	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	
⅜	·259	·07	·278	·08	·292	·08	·322	·09	⅜
½	·314	·16	·336	·17	·363	·19	·388	·20	½
¾	·408	·47	·436	·50	·470	·54	·502	·58	¾
1	·489	1·00	·522	1·07	·562	1·15	·600	1·22	1
1¼	·562	1·79	·600	1·91	·644	2·05	·687	2·19	1¼
1½	·629	2·88	·670	3·08	·720	3·30	·767	3·52	1½
1¾	·690	4·31	·736	4·60	·790	4·94	·842	5·26	1¾
2	·749	6·11	·798	6·51	·856	6·98	·911	7·44	2
2½	·856	10·91	·911	11·62	·977	12·46	1·04	13·26	2½
3	·954	17 51	1·02	18 66	1·09	19·98	1 16	21 25	3
4	1·13	36·89	1·20	39·23	1·29	42·02	1·37	44·67	4
5	1·29	65·65	1·37	69·79	1·47	74·71	1·56	79·39	5
6	1·43	105·08	1·52	111·66	1·63	119·49	1·73	126·92	6
7	1·56	156·32	1·66	166·07	1·78	176·64	1·89	188·64	7
8	1·69	220·34	1·79	234·11	1·92	250·37	2·04	265 81	8
9	1·81	298·41	1·92	316·87	2·04	337·70	2·18	359·63	9
10	1·92	391·20	2 04	415·34	2·18	443·98	2·31	471·18	10
11	2·02	499·69	2·15	530·42	2·30	566·91	2·44	601·58	11
12	2·13	624·73	2·26	663·07	2·41	708·58	2·56	751·80	12
15	2·41	1106·9	2·56	1174·7	2·73	1254·8	2·90	1331·0	15
18	2·67	1766·1	2·83	1873·4	3·03	2000·6	3·21	2121·5	18
24	3·14	3686·8	3·33	3909·2	3·55	4172·9	3·76	4423·2	24
30	3·55	6520·2	3 76	6911·3	4·02	7373·8	4·26	7826·8	30

CYLINDRICAL PIPES—*continued.*

Diameter of pipe in inches.	Head of Water divided by Length of Pipe. $\frac{2\cdot75}{1000}$ Velocity in feet per second.	$\frac{2\cdot75}{1000}$ Supply in gallons per minute.	$\frac{3}{1000}$ Velocity in feet per second.	$\frac{3}{1000}$ Supply in gallons per minute.	$\frac{3\cdot5}{1000}$ Velocity in feet per second.	$\frac{3\cdot5}{1000}$ Supply in gallons per minute.	$\frac{4}{1000}$ Velocity in feet per second.	$\frac{4}{1000}$ Supply in gallons per minute.	Diameter of pipe in inches.
$\frac{3}{8}$	·343	·10	·363	·10	·401	·11	·436	·13	$\frac{3}{8}$
$\frac{1}{2}$	·413	·21	·436	·22	·481	·25	·522	·27	$\frac{1}{2}$
$\frac{3}{4}$	·532	·61	·562	·64	·618	·71	·670	·77	$\frac{3}{4}$
1	·636	1·30	·670	1·37	·736	1·50	·798	1·63	1
1¼	·723	2·32	·770	2·45	·842	2·63	·911	2·90	1¼
1½	·812	3·73	·856	3·93	·933	4·31	1·02	4·67	1½
1¾	·891	5·56	·938	5·86	1·03	6·42	1·11	6·94	1¾
2	·963	7·86	1·02	8·29	1·11	9·07	1·20	9·81	2
2½	1·10	14·04	1·16	14·76	1·27	16·15	1·37	17·45	2½
3	1·22	22·47	1·29	23·64	1·41	25·85	1·52	27·92	3
4	1·45	47·20	1·52	49·63	1·66	54·23	1·79	58·53	4
5	1·64	83·85	1·73	88·14	1·89	96·24	2·04	103·84	5
6	1·83	134·02	1·92	140·83	2·09	153·71	2·26	165·77	6
7	1·99	199·15	2·09	209·22	2·28	228·27	2·46	246·10	7
8	2·15	280·56	2·26	294·70	2·46	321·43	2·65	346·45	8
9	2·30	379·51	2·41	398·58	2·63	434·62	2·83	468·35	9
10	2·44	497·18	2·56	522·08	2·79	569·18	3·01	613·22	10
11	2·57	634·68	2·70	666·39	2·94	726·35	3·17	782·42	11
12	2·70	793·09	2·83	832·63	3·09	907·39	3·33	977·29	12
15	3·06	1403·6	3·21	1473·2	3·50	1604·8	3·76	1727·8	15
18	3·38	2236·8	3·55	2347·2	3·87	2556·1	4·16	2751·4	18
24	3·97	4662·2	4·16	4891·4	4·53	5323·6	4·88	5727·8	24
30	4·49	8235·9	4·71	8638·9	5·12	9399·2	5·51	10109·7	30

CYLINDRICAL PIPES—*continued.*

Diameter of pipe in inches.	Head of Water divided by Length of Pipe. $\frac{4\cdot5}{1000}$ Velocity in feet per second.	$\frac{4\cdot5}{1000}$ Supp'y in gallons per minute.	$\frac{5}{1000}$ Velocity in feet per second.	$\frac{5}{1000}$ Supply in gallons per minute.	$\frac{6}{1000}$ Velocity in feet per second.	$\frac{6}{1000}$ Supply in gallons per minute.	$\frac{7}{1000}$ Velocity in feet per second.	$\frac{7}{1000}$ Supply in gallons per minute.	Diameter of pipe in inches.
⅜	·470	·13	·502	·14	·562	·16	·618	·18	⅜
½	·562	·29	·600	·31	·670	·34	·736	·38	½
¾	·720	·83	·770	·88	·856	·98	·938	1·08	¾
1	·856	1·75	·911	1·86	1·02	2·08	1·11	2·27	1
1¼	·977	3·11	1·01	3·31	1·16	3·69	1·27	4·04	1¼
1½	1·09	4·99	1·16	5·44	1·29	5·91	1·41	6·46	1½
1¾	1·19	7·44	1·27	7·91	1·41	8·79	1·55	9·68	1¾
2	1·29	10·50	1·37	11·17	1·52	12·41	1·66	13·56	2
2½	1·47	18·68	1·56	19·85	1·73	22·04	1·82	23·30	2½
3	1·63	29·87	1·73	31·73	1·92	35·21	2·09	38·43	3
4	1·92	62·59	2·04	66·46	2·26	73·68	2·46	80·36	4
5	2·18	111·00	2·31	117·80	2·56	130·52	2·79	142·30	5
6	2·41	177·14	2·56	187·95	2·83	208·16	3·09	226·84	6
7	2·63	262·91	2·79	278·90	3·09	308·76	3·37	335·60	7
8	2·83	370·05	3·01	392·46	3·33	434·35	3·62	473·09	8
9	3·03	500·16	3·21	530·36	3·55	586·82	3·87	639·02	9
10	3·21	654·78	3·40	694·24	3·76	767·92	4·09	833·58	10
11	3·38	835·34	3·59	885·56	3·97	979·39	4·32	1066·1	11
12	3·55	1043·2	3·76	1105·8	4·16	1222·9	4·53	1331·8	12
15	4·02	1843·4	4·26	1956·7	4·71	2159·7	5·12	2349·8	15
18	4·44	2935·6	4·71	3110·0	5·18	3426·1	5·65	3737·0	18
24	5·20	6108·8	5·51	6470·3	6·08	7145·4	6·61	7769·1	24
30	5·87	10779·7	6·22	11415·0	6·86	12601·3	7·50	13772·4	30

CYLINDRICAL PIPES—*continued.*

Diameter of pipe in inches.	Head of Water divided by Length of Pipe.								Diameter of pipe in inches.
	$\frac{8}{1000}$		$\frac{9}{1000}$		$\frac{10}{1000}$		$\frac{12}{1000}$		
	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	
$\frac{3}{8}$	·670	·19	·720	·21	·770	·22	·856	·25	$\frac{3}{8}$
$\frac{1}{2}$	·798	·41	·856	·44	·911	·46	1·02	·52	$\frac{1}{2}$
$\frac{3}{4}$	1·02	1·17	1·09	1·24	1·16	1·33	1·29	1·48	$\frac{3}{4}$
1	1·20	2·45	1·29	2·63	1·37	2·79	1·52	3·10	1
$1\frac{1}{4}$	1·37	4·36	1·47	4·67	1·56	4·96	1·73	5·51	$1\frac{1}{4}$
$1\frac{1}{2}$	1·52	6·98	1·63	7·47	1·73	7·93	1·92	8·80	$1\frac{1}{2}$
$1\frac{3}{4}$	1·66	10·33	1·78	11·[illegible]0	1·89	11·79	2·09	13·08	$1\frac{3}{4}$
2	1·79	14·63	1·92	15·65	2·04	16·61	2·26	18·42	2
$2\frac{1}{2}$	2·04	25·96	2·18	27·75	2·31	29·45	2·56	32·63	$2\frac{1}{2}$
3	2·26	41·44	2·41	44·29	2·56	46·99	2·83	52·04	3
4	2·65	86·61	2·83	92·51	3·01	98·60	3·33	108·59	4
5	3·01	153·31	3·21	163·69	3·40	173·70	3·76	189·78	5
6	3·33	244·32	3·55	260·81	3·76	277 10	4·16	305·71	6
7	3·62	362·21	3·87	386·57	4·09	408·45	4·53	452·87	7
8	3·90	509·38	4·16	543·49	4·41	575·83	4·88	636·42	8
9	4·16	637·85	4·44	733·83	4·71	777·50	5·20	857·30	9
10	4·41	899·75	4·71	959·88	4·99	1016·9	5·51	1123·3	10
11	4·65	1147·2	4·96	1223·7	5·26	1298·4	5·80	1431·7	11
12	4·88	1432·0	5·18	1522·7	5·51	1617·6	6·08	1786·4	12
15	5·51	2527·4	5·87	2694·9	6·22	2853·8	6·86	3150·3	15
18	6·08	4019·3	6·48	4284·7	6·86	4536·5	7·58	5006·5	18
24	7·11	8351·6	7·58	8900·4	8·02	9421·1	8·85	10392·3	24
30	8·02	14720·4	8·54	15684·5	9·04	16599·0	10·07	18482·9	30

CYLINDRICAL PIPES—*continued.*

Diameter of pipe in inches.	Head of Water divided by Length of Pipe. $\frac{14}{1000}$ Velocity in feet per second.	$\frac{14}{1000}$ Supply in gallons per minute.	$\frac{16}{1000}$ Velocity in feet per second.	$\frac{16}{1000}$ Supply in gallons per minute.	$\frac{18}{1000}$ Velocity in feet per second.	$\frac{18}{1000}$ Supply in gallons per minute.	$\frac{20}{1000}$ Velocity in feet per second.	$\frac{20}{1000}$ Supply in gallons per minute.	Diameter of pipe in inches.
⅜	·938	·27	1·02	·29	1·09	·31	1 16	·33	⅜
½	1·11	·57	1·20	·61	1·29	·66	1·37	·70	½
¾	1·41	1·62	1·52	1·74	1·63	1·87	1·73	1 98	¾
1	1·66	3·39	1·79	3·66	1·92	3·91	2·04	4·15	1
1¼	1·89	6·02	2·04	6·49	2·18	6·94	2 31	7·36	1¼
1½	2·09	9·61	2·26	10·36	2·41	11 07	2·56	11·75	1½
1¾	2·28	14·27	2·46	15·38	2·63	16·43	2·79	17·43	1¾
2	2 46	20·09	2·65	21·65	2·83	23·13	3·01	24·53	2
2½	2·79	35·57	3·01	38·32	3·21	40·92	3·40	43·39	2½
3	3·09	56·71	3·33	61·08	3·55	65·20	3·76	69·11	3
4	3·62	118·27	3·90	127·33	4·16	135·87	4·41	144·20	4
5	4·10	209·02	4·41	224·94	4·71	239·97	4·99	254·50	5
6	4·53	332·72	4·88	357·99	5·20	381·80	5·51	404·30	6
7	4·87	486·99	5·30	530·09	5·66	565·26	5·99	598·62	7
8	5·30	692·36	5·70	744·66	6·08	793·93	6·44	840·68	8
9	5·66	934·41	6·08	1004·8	6·48	1071·2	6·86	1134·1	9
10	5·99	1221·7	6·44	1313·6	6·86	1400·1	7·27	1482·3	10
11	6·31	1556·8	6·78	1673·7	7·23	1783 9	7·65	1888·3	11
12	6·61	1942·3	7·11	2087·9	7·58	2225·1	8·02	2355·3	12
15	7·50	3443·1	8·02	3680·1	8·54	3921·1	9·04	4149·7	15
18	8·23	5440·5	8·85	5845·7	9·42	6227·8	10·07	6653·8	18
24	9·56	11226·5	10·32	12127·5	10·99	12915·5	11·63	13664·4	24
30	10·83	19880·1	11·63	21355·7	12·39	22742·5	13·10	23993·0	30

CYLINDRICAL PIPES—*continued.*

Diameter of pipe in inches.	Head of Water divided by Length of Pipe.								Diameter of pipe in inches.
	$\frac{22 \cdot 5}{1000}$		$\frac{25}{1000}$		$\frac{27 \cdot 5}{1000}$		$\frac{30}{1000}$		
	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	
$\frac{3}{8}$	1·21	·35	1·32	·38	1·39	·40	1·47	·42	$\frac{3}{8}$
$\frac{1}{2}$	1·47	·75	1·56	·79	1·64	·84	1·73	·88	$\frac{1}{2}$
$\frac{3}{4}$	1·85	2·12	1·96	2·25	2·07	2·38	2·18	2·50	$\frac{3}{4}$
1	2·18	4·44	2·31	4·71	2·44	4·97	2·56	5·22	1
$1\frac{1}{4}$	2·47	7·87	2·62	8·35	2·76	8·80	2·90	9·24	$1\frac{1}{4}$
$1\frac{1}{2}$	2·73	12·55	2·90	13·31	3·06	14·04	3·21	14·73	$1\frac{1}{2}$
$1\frac{3}{4}$	2·98	18·62	3·16	19·74	3·33	20·81	3·50	21·84	$1\frac{3}{4}$
2	3·21	26·19	3·40	27·77	3·58	29·24	3·76	30·72	2
$2\frac{1}{2}$	3·63	46·31	3·85	49·09	4·06	51·74	4·26	54·35	$2\frac{1}{2}$
3	4·02	73·74	4·26	78·27	4·49	82·36	4·71	86·39	3
4	4·71	153·58	4·99	162·70	5·26	171·69	5·51	179·73	4
5	5·32	271·12	5·63	287·15	5·93	302·41	6·22	317·08	5
6	5·87	431·19	6·22	456·60	6·55	480·84	6·86	504·05	6
7	6·39	638·26	6·76	675·69	7·12	711·46	7·50	749·83	7
8	6·86	896·09	7·27	948·66	7·65	998·78	8·02	1046·8	8
9	7·27	1201·8	7·74	1279·5	8·15	1347·0	8·54	1411·6	9
10	7·74	1579·6	8·20	1672·0	8·63	1760·0	9·04	1844·3	10
11	8·15	2012·2	8·63	2129·6	9·08	2241·6	9·52	2348·8	11
12	8·54	2509·5	9·04	2655·8	9·52	2795·2	9·97	2928·7	12
15	9·63	4420·6	10·19	4677·5	10·73	4922·4	11·24	5157·0	15
18	10·62	7018·9	11·24	7425·8	11·82	7813·5	12·38	8184·8	18
24	12·39	14555·3	13·10	15390·9	13·78	16191·8	14·43	16958·3	24
30	13·95	25603·6	14·75	27078·1	15·52	28483·2	16·25	29828·1	30

CYLINDRICAL PIPES—*continued.*

Diameter of pipe in inches.	Head of Water divided by Length of Pipe.								Diameter of pipe in inches.
	$\frac{35}{1000}$		$\frac{40}{1000}$		$\frac{45}{1000}$		$\frac{50}{1000}$		
	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	Velocity in feet per second.	Supply in gallons per minute.	
⅜	1·60	·46	1·73	·50	1·85	·53	1·96	·56	⅜
½	1·89	·96	2·04	1·04	2·18	1·11	2·31	1·18	½
¾	2·37	2 72	2·56	2·94	2·73	3·14	2·90	3·33	¾
1	2·79	5 69	3·01	6·13	3·21	6·55	3·40	6·94	1
1¼	3·16	10·07	3·40	10·85	3·63	11·58	3 85	12·27	1¼
1½	3·50	16·05	3·76	17·28	4·02	18·43	4·26	19·57	1½
1¾	3·81	23·79	4·09	25·53	4·37	27·32	4·63	28·95	1¾
2	4·10	33·44	4·41	35·99	4·71	38·40	4·99	40·67	2
2½	4·63	59·07	4·99	63·55	5·32	67·78	5·63	71·79	2½
3	5·12	93·99	5·51	101·10	5·87	107·80	6·22	114·15	3
4	5·99	195·47	6·44	210·17	6·86	224·02	7 27	237·17	4
5	6·76	344·74	7·27	370·57	7·74	394·91	8·20	418·02	5
6	7·50	550·90	8·02	588·82	8·54	627·38	9·04	663·96	6
7	8·11	810·40	8·71	870·78	9·28	927·69	9·82	981·68	7
8	8·71	1137·3	9·36	1222·0	9·97	1301·7	10·55	1377·3	8
9	9·28	1533·5	9·97	1647·4	10·62	1754·7	11·24	1856·4	9
10	9·82	20[illegible]3·4	10·55	2152·0	11·24	2291·9	11·89	2424·5	10
11	10·35	2553·6	11·10	2740·1	11·82	2918·0	12·49	3082·9	11
12	10·83	3180·8	11 63	3416·1	12·39	3638·8	13·10	3838·9	12
15	12·20	5599·1	13·10	5998·2	13·95	6401·2	14·75	6769·5	15
18	13·45	8891·1	14·43	9539·1	15·37	10154·6	16·25	10738·1	18
24	15·66	18404·4	16·81	19754·1	17·89	21024·5	18·92	22228·8	24
30	17·64	32381·0	18·92	34732·5	20·13	36961·1	21·28	39073·2	30

CYLINDRICAL PIPES—*continued.*

Diameter of pipe in inches.	Head of Water divided by Length of Pipe. $\frac{60}{1000}$ Velocity in feet per second.	$\frac{60}{1000}$ Supply in gallons per minute.	$\frac{70}{1000}$ Velocity in feet per second.	$\frac{70}{1000}$ Supply in gallons per minute.	$\frac{80}{1000}$ Velocity in feet per second.	$\frac{80}{1000}$ Supply in gallons per minute.	$\frac{90}{1000}$ Velocity in feet per second.	$\frac{90}{1000}$ Supply in gallons per minute.	Diameter of pipe in inches.
⅜	2·18	·62	2·37	·68	2·56	·73	2·74	·79	⅜
½	2·56	1·31	2·79	1·42	3·01	1·53	3·21	1·64	½
¾	3·21	3·68	3·50	4·01	3·76	4·32	4·01	4·60	¾
1	3·76	7·68	4·09	8·34	4·41	9·00	4·71	9·60	1
1¼	4·26	13·59	4·63	14·77	4·99	15·89	5·32	16·94	1¼
1½	4·71	21·60	5·12	23·50	5·51	25·27	5·87	26·95	1½
1¾	5·12	31·98	5·57	34·79	5·99	37·41	6·38	39·89	1¾
2	5·51	44·93	5·99	48·87	6·44	52·54	6·86	56·01	2
2½	6·22	79·27	6·76	86·18	7·27	92·64	7·74	98·70	2½
3	6·86	126·01	7·50	137·72	8·02	147·20	8·54	156·85	3
4	8·02	261·70	8·71	284·34	9·36	305·50	9·97	325·41	4
5	9·04	461·08	9·82	500·86	10·55	537·99	11·24	572·99	5
6	9·97	732·18	10·83	795·20	11·63	854·02	12·38	909·42	6
7	10·83	1082·4	11·76	1175·3	12·63	1262·1	13·44	1343·7	7
8	11·63	1518·3	12·63	1648·4	13·56	1765·8	14·43	1884·3	8
9	12·38	2046·2	13·44	2221·3	14·43	2384·8	15·36	2538·6	9
10	13·10	2665·9	14·22	2900·4	15·26	3113·5	16·25	3314·2	10
11	13·78	3401·4	14·96	3691·7	16·06	3962·7	17·09	4217·9	11
12	14·43	4239·6	15·66	4601·1	16·81	4938·6	17·89	5256·2	12
15	16·25	7457·0	17·63	8091·3	18·92	8683·1	20·13	9240·3	15
18	17·89	11826·3	19·41	12830·1	20·83	13766·8	22·16	14648·5	18
24	20·83	24474·3	22·59	26545·4	24·24	28477·6	25·79	30296·3	24
30	23·43	43 11·1	25·41	46642·4	27·25	50029·4	28·99	53218·5	30

CYLINDRICAL PIPES—*continued.*

Diameter of pipe in inches.	Head of Water divided by Length of Pipe. 100/1000 Velocity in feet per second.	100/1000 Supply in gallons per minute.	200/1000 Velocity in feet per second.	200/1000 Supply in gallons per minute.	300/1000 Velocity in feet per second.	300/1000 Supply in gallons per minute.	400/1000 Velocity in feet per second.	400/1000 Supply in gallons per minute.	Diameter of pipe in inches.
3/8	2·90	·83	4·26	1·22	5·32	1·52	6·22	1·78	3/8
1/2	3·40	1·74	4·99	2·54	6·22	3·17	7 27	3·71	1/2
3/4	4·26	4·89	6·22	7·13	7·74	8·89	9·04	10·37	3/4
1	4·99	10·17	7·27	14·82	9·04	18·44	10·55	21·52	1
1¼	5·63	17·95	8·20	26·13	10·19	32·48	11·89	37·88	1¼
1½	6·22	28·54	9·0[illegible]	41·[illegible]0	11·24	51·57	13·10	59·98	1½
1¾	6·76	42·23	9·82	61·35	12·20	76·21	14·22	88·82	1¾
2	7·27	59·29	10·55	86·08	13·10	1[illegible]6 64	15·26	124 54	2
2½	8·20	104·50	11·89	151·53	14·75	183·42	17·18	219·03	2½
3	9·04	165·99	13·10	239·93	16·25	298·28	18·92	347·32	3
4	10·55	344·32	15·26	498·17	18·92	617·47	22·02	718·66	4
5	11·[illegible]9	606·13	17·18	876·11	21·28	10[illegible]5·4	24·76	1262·8	5
6	13·10	959·72	18·92	1389·3	23·43	1720·4	27·25	2[illegible]01·2	6
7	14·22	1421·2	20·52	2051·3	25·41	2539·4	29·55	2953·2	7
8	15·26	1992·7	22·02	2874·7	27·25	3557·6	31·67	4134·9	8
9	16·25	2684·5	23·43	3871·0	28·[illegible]9	4789·7	33·70	556[illegible]·3	9
10	17 18	3504·5	24·76	5051·3	30·63	6246·9	35·60	7262·3	10
11	18·07	4459·7	26 04	6425·9	32·20	7947·9	37·41	923[illegible]·4	11
12	18·92	5557·2	27·25	8004·7	33·70	9899·2	39·17	11504·2	12
15	21·28	9768·3	30·63	14059·7	37·87	1738[illegible]·0	44·00	20192·7	15
18	23·43	15484 0	33·70	22273·1	41 65	27524·2	48·38	31972·0	18
24	27·25	32018 8	39·17	46016·9	48·38	56839·1	56·18	66[illegible]05·2	24
30	30·63	56238·9	44·0	80770·7	54·33	99731·6	63·07	115785·	30

CYLINDRICAL PIPES—*continued.*

Diameter of pipe in inches.	Head of Water divided by Length of Pipe. $\frac{500}{1000}$ Velocity in feet per second.	$\frac{500}{1000}$ Supply in gallons per minute.	$\frac{600}{1000}$ Velocity in feet per second.	$\frac{600}{1000}$ Supply in gallons per minute.	$\frac{700}{1000}$ Velocity in feet per second.	$\frac{700}{1000}$ Supply in gallons per minute.	$\frac{800}{1000}$ Velocity in feet per second.	$\frac{800}{1000}$ Supply in gallons per minute.	Diameter of pipe in inches.
$\frac{3}{8}$	7·02	2·01	7·74	2·22	8·42	2·41	9·04	2·59	$\frac{3}{8}$
$\frac{1}{2}$	8·20	4·18	9·04	4·61	9·82	5·01	10·55	5·38	$\frac{1}{2}$
$\frac{3}{4}$	10·19	11·69	11·24	12·89	12·20	14·00	13·10	15·00	$\frac{3}{4}$
1	11·89	24·25	13·10	26·66	14·22	29·00	15·26	31·14	1
$1\frac{1}{4}$	13·39	42·67	14·75	47·01	16·01	51·02	17·18	54·76	$1\frac{1}{4}$
$1\frac{1}{2}$	14·75	67·70	16·25	74·57	17·63	80·91	18·92	86·83	$1\frac{1}{2}$
$1\frac{3}{4}$	16·01	99·99	17·63	110·14	19·13	119·48	20·32	128·21	$1\frac{3}{4}$
2	17·18	140·18	18·92	154·37	20·52	167·45	22·02	179·67	2
$2\frac{1}{2}$	19·33	246·46	21·28	271·34	23·08	294·29	24·76	315·71	$2\frac{1}{2}$
3	21·28	390·73	23·43	430·11	25·41	466·42	27·25	500·29	3
4	24·76	808·21	25·25	824·14	29·55	964·31	31·67	1033·7	4
5	27·84	1419·8	30·63	1561·7	33·21	1692·6	35·60	1815·6	5
6	30·63	2248·9	33·70	2474·8	36·53	2682·4	39·17	2876·1	6
7	33·21	3319·2	36·53	3651·1	39·59	3957·0	42·44	4242·3	7
8	35·60	4647·9	39·17	5113·0	42·44	5510·9	45·50	5940·0	8
9	37·87	6256·8	41·65	6881·1	45·13	7456·4	48·38	7993·0	9
10	40·01	8161·0	44·00	8974·3	47·67	9724·4	51·10	10423·5	10
11	42·00	10365·4	46·24	11411·6	50·10	12364·4	53·70	13252·8	11
12	44·00	12923·0	48·38	14209·8	52·40	15391·1	56·18	16501·3	12
15	49·42	22679·2	54·33	24932·9	58·85	27009·8	63·07	28946·2	15
18	54·33	35903·4	59·72	39465·9	64·52	42641·5	69·32	45811·5	18
24	63·07	74102·4	69·32	81442·6	75·07	88204·4	80·44	94508·9	24
30	70·80	129971·	77·80	142825·	84·25	154668·	90·26	165708·	30

The following general laws relating to the flow of water will enable the foregoing Table to be applied to other conditions of head, diameter, &c., than those given:

1st. When the *head* and *length* of pipes remain constant the supply varies as the square root of the fifth power of the diameter, or as $d^{2\cdot5}$.

2nd. The *diameter* and *length* remaining constant the supply varies directly as the square root of the head $= \sqrt{H}$.

3rd. When the *diameter* and *head* are constant the supply will be inversely as the square root of the length.

Comparative Discharging Power of Pipes.

Diameter of Pipe.	$d^{2\cdot5}$	Diameter of Pipe.	$d^{2\cdot5}$	Diameter of Pipe.	$d^{2\cdot5}$	Diameter of Pipe.	$d^{2\cdot5}$
in.		in.		in.		in.	
¼	·031	2¼	9·88	8	181·0	18	1375
⅜	·086	2¾	12·54	9	243·0	20	1789
½	·177	3	15·59	10	316·2	22	2270
¾	·485	3½	22·92	11	401·3	24	2822
1	1·	4	32·00	12	498·8	26	3447
1¼	1·747	4½	42·96	13	609·3	28	4149
1½	2·756	5	55·90	14	733·4	30	4930
1¾	4·051	5½	70·94	15	871·4	32	5793
2	5·657	6	88·18	16	1024·0	34	6741
2¼	7·594	7	129·6	17	1191·6	36	7776

DRAINS.

In sewers provide for removing of rainfall per hour.

	Inches in depth.
From roofs (horizontal measure)	·5
„ flagged surfaces	·2
„ paved „	·1
„ gravel „ clay subsoil	·05
„ „ „ gravel or chalk ditto	·01
„ meadows or grass plots	·02

In the open country where the soil is loose and permeable about $\frac{1}{3}$rd only of the rainfall finds its way into the watercourses, the remaining $\frac{2}{3}$rds being absorbed or evaporated.

In ordinary country towns, depending on the extent of the suburbs and the state of the pavements, from $\frac{1}{4}$th to $\frac{1}{3}$rd of the rainfall due to a given period, should be provided to be removed by the sewers within one hour after it ceases. In large well-paved cities one-half of the quantity may be assumed as passing into the sewers within the same time.

Of sewage, provide for removing 5 cubic feet per head of men, women, and children in 24 hours, one-half to be calculated as passing off in about 6 hours. The total quantity to be removed should never be estimated at less than the water supply.

The amount of solid matter in town sewage where the water supply is abundant, varies from 1 part in 300 to 1 part in 600.

House drains leading from more than one water-closet should be 6 inches diameter, and laid with a

fall of not less than 1 inch in 10 feet, and where possible 1 inch in 5 feet. Branch drains from sinks may be 4 inches diameter, with a fall of 1 inch in 6 feet.

A velocity of about 3 feet per second is required to keep house drains clear, and 2 feet per second for main sewers. These velocities should be increased for small pipes, say for house drains 6 inches diameter and under to 4 feet per second, and for mains 12 inches diameter and under to 3 feet per second.

The following Table shows the fall to be given to cylindrical sewers flowing full to ensure these velocities.

Diam. in inches.	Velocity 2 feet per second.		Velocity 3 feet per second.		Velocity 4 feet per second.	
	Inclination.	Discharge in gall. per min.	Inclination.	Discharge in gall. per min.	Inclination.	Discharge in gall. per min.
4	1 in 200	65	1 in 100	98	1 in 60	130
6	„ 286	147	„ 143	220	„ 85	294
9	„ 400	330	„ 222	496	„ 125	661
12	„ 621	583	„ 286	881	„ 172	1175
15	„ 769	918	„ 370	1377	„ 222	1836
18	„ 893	1322	„ 400	1983	„ 279	2644
24	„ 1110	2350	„ 581	3525	„ 362	4700
30	„ 1400	3673	„ 724	5508	„ 400	7344

Except where sewage is used for irrigation, &c., all rain water should, as a rule, be allowed to pass off by the sewers, for the purpose of flushing them.

The formula used for calculating the size of open channels and pipes for water supply applies also to sewers, except that the latter are usually taken as flowing from $\frac{1}{2}$ to $\frac{2}{3}$rds full. In which case the value

of R must be found by dividing the area of the transverse section of the part filled by the girth of the bottom and sides which are in contact with the sewage. In cylindrical pipes, flowing $\frac{1}{2}$ full R = $\frac{1}{4}$th of the diameter, the same as for pipes entirely filled, when the sectional area of the sewage is $\frac{2}{3}$rds that of the pipe R = diameter × ·292, and when $\frac{3}{4}$ths R = diameter × ·296.

For egg-shaped sewers, of which the conjugate diameter is $1\frac{1}{2}$ times the transverse diameter, when flowing about $\frac{2}{3}$rds full, as in sketch, the following formulæ may be used:

$$V = 15{\cdot}3 \sqrt{d S},$$

$$Q = {\cdot}08 \sqrt{d^5 S},$$

d being the transverse diameter in inches.

Other forms of sewer may be calculated by the formulæ for open channels.

Size of Stoneware Drain Pipes.

Internal Diameter.	Thickness.	Length when laid.	Depth of Socket.
inches.	inches.	feet.	inches.
3	$\frac{3}{8}$	2·0	$1\frac{1}{4}$
4	$\frac{1}{2}$	"	$1\frac{1}{2}$
6	$\frac{5}{8}$	"	$1\frac{3}{4}$
9	$\frac{3}{4}$	"	2
12	1	"	2
15	$1\frac{1}{8}$	"	$2\frac{1}{4}$
18	$1\frac{1}{4}$	"	$2\frac{1}{2}$
24	$1\frac{3}{8}$	2·5	3

Cylindrical Sewers.—Table showing the velocity in feet per second, and the discharge in cubic feet per minute, when flowing one half full. Calculated from the formula $V = 140\sqrt{RS} - 11\sqrt[3]{RS}$.

Diameter in inches.	Fall divided by Length of Pipe. $\frac{1}{10000}$ Velocity in feet per second.	$\frac{1}{10000}$ Discharge in cubic feet per minute.	$\frac{2}{10000}$ Velocity in feet per second.	$\frac{2}{10000}$ Discharge in cubic feet per minute.	$\frac{3}{10000}$ Velocity in feet per second.	$\frac{3}{10000}$ Discharge in cubic feet per minute.	$\frac{4}{10000}$ Velocity in feet per second.	$\frac{4}{10000}$ Discharge in cubic feet per minute.	Diameter in inches.
2	·109	·071	·185	·121	·240	·157	·291	·191	2
3	·147	·217	·240	·353	·315	·464	·378	·557	3
4	·185	·484	·291	·762	·378	·990	·455	1·19	4
6	·240	1·41	·378	2·23	·490	2·89	·585	3·45	6
9	·315	4·18	·490	6·49	·620	8·22	·749	9·93	9
12	·378	8·91	·585	13·78	·749	17·65	·889	20·95	12
15	·436	16·05	·670	24·67	·856	31·51	1·019	37·16	15
18	·490	25·98	·749	39·71	·954	50·58	1·130	59·91	18
21	·538	38·82	·820	59·17	1·043	75·26	1·237	89·26	21
24	·585	55·14	·889	83·79	1·130	106·5	1·337	126·0	24
30	·670	98·67	1·019	150·1	1·287	189·5	1·521	224·0	30
36	·749	158·8	1·130	239·6	1·440	305·4	1·700	360·5	36

Diameter in inches.	Fall divided by Length of Pipe.								Diameter in inches.
	$\frac{5}{10000}$		$\frac{6}{10000}$		$\frac{7}{10000}$		$\frac{8}{10000}$		
	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	
2	·336	·220	·378	·247	·417	·273	·455	·298	2
3	·436	·642	·490	·722	·537	·791	·585	·862	3
4	·522	1·37	·585	1·53	·640	1·68	·697	·83	4
6	·670	3·95	·749	4·41	·823	4·82	·889	5·24	6
9	·856	11·35	·954	12·64	1·043	13·82	1·130	14·98	9
12	1·019	24·02	1·130	26·63	1·237	29·15	1·337	31·50	12
15	1·158	42·63	1·287	47·38	1·408	51·84	1·520	55·96	15
18	1·287	68·23	1·440	76·34	1·564	82·92	1·700	90·13	18
21	1·408	101·6	1·564	112·9	1·709	123·3	1·845	133·1	21
24	1·521	143·4	1·700	160·2	1·845	173·9	1·989	187·5	24
30	1·728	254·5	1·918	282·5	2·093	308·2	2·257	332·4	30
36	1·918	406·7	2·127	451·0	2·320	490·8	2·502	530·6	36

Cylindrical Sewers—*continued*.

Diameter in inches.	Fall divided by Length of Pipe.								Diameter in inches.
	$\frac{9}{10000}$		$\frac{1}{1000}$		$\frac{2}{1000}$		$\frac{3}{1000}$		
	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	
2	·490	·321	·522	·342	·798	·522	1·019	·667	2
3	·620	·913	·670	·987	1·019	1·50	1·287	1·90	3
4	·749	1·96	·798	2·09	1·202	3·15	1·521	3·98	4
6	·954	5·62	1·019	6·00	1·521	8·96	1·918	11·30	6
9	1·211	16·05	1·287	17·06	1·918	25·42	2·412	31·97	9
12	1·440	33·93	1·521	35·84	2·257	53·18	2·835	66·80	12
15	1·627	59·90	1·728	63·62	2·560	94·25	3·210	118·2	15
18	1·806	95·75	1·918	101·6	2·835	150·3	3·552	188·3	18
21	1·972	142·3	2·093	151·0	3·093	223·2	3·868	279·1	21
24	2·127	200·5	2·257	212·7	3·327	313·6	4·163	392·4	24
30	2·412	355·2	2·560	377·0	3·765	554·4	4 706	693·0	30
36	2·672	566·6	2·835	601·2	4·163	882·8	5·184	1099·3	36

Diameter in inches.	Fall divided by Length of Pipe.								Diameter in inches.
	$\frac{4}{1000}$		$\frac{5}{1000}$		$\frac{6}{1000}$		$\frac{7}{1000}$		
	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	
2	1·202	·787	1·369	·896	1·521	·996	1·662	1·09	2
3	1·521	2·24	1·728	2·55	1·918	2·82	2·093	3·08	3
4	1·793	4·69	2·036	5·33	2·257	5·91	2·462	6·45	4
6	2·257	13·30	2·560	15·08	2·835	16·70	3·089	18·20	6
9	2·835	37·57	3·210	42·54	3·552	47·08	3·868	51·27	9
12	3·327	78·39	3·765	88·71	4·163	98·09	4·534	106·8	12
15	3·765	138·6	4·263	156·9	4·706	173·3	5·120	188·5	15
18	4·163	220·7	4·706	249·5	5·184	274·8	5·654	299·7	18
21	4·531	327·0	5·120	369·5	5·655	408·1	6·150	443·8	21
24	4·875	459·5	5·507	519·0	6·082	573·2	6·612	623·2	24
30	5·507	811·0	6·218	915·7	6·864	1010·8	7·502	1104·8	30
36	6·082	1289·7	6·864	1455·6	7·575	1606·3	8·232	1745·7	36

Cylindrical Sewers—*continued.*

Diameter in inches.	Fall divided by Length of Pipe.								Diameter in inches.
	$\frac{8}{1000}$		$\frac{9}{1000}$		$\frac{1}{100}$		$\frac{2}{100}$		
	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	
2	1·793	1·17	1·918	1·26	2·036	1·33	3·006	1·97	2
3	2·257	3·32	2·412	3·55	2·560	3·77	2·765	5·54	3
4	2·654	6·95	2·835	7·42	3·066	7·87	4·411	11·55	4
6	3·327	19·60	3·552	20·92	3·765	22·18	5·507	32·44	6
9	4·163	55·18	4·441	58·86	4·706	62·37	6·864	90·97	9
12	4·875	114·9	5·185	122·2	5·507	129·8	8·019	188·9	12
15	5·507	202·7	5·872	216·2	6·218	228·9	9·042	332·9	15
18	6·082	322·4	6·483	343·7	6·864	363·9	10·068	533·8	18
21	6·612	477·1	7·048	508·6	7·502	541·3	10·829	781·4	21
24	7·103	669·9	7·575	713·9	8·019	755·8	11·630	1096·1	24
30	8·019	1180·9	8·544	1258·2	9·042	1331·6	13·100	1929·1	30
36	8·845	1875·7	9·423	1998·2	9·971	2114·4	14·434	3060·9	36

CYLINDRICAL SEWERS—*continued.*

Diameter in inches.	Fall divided by Length of Pipe.								Diameter in inches.
	$\frac{3}{100}$		$\frac{4}{100}$		$\frac{5}{100}$		$\frac{6}{100}$		
	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	Velocity in feet per second.	Discharge in cubic feet per minute.	
2	3·765	2·46	4·411	2·89	4·985	3·26	5·507	3·60	2
3	4·706	6·93	5 507	8·11	6·218	9·14	6·864	10·10	3
4	5·507	14·42	6·440	16·86	7·267	19·03	8·019	20·99	4
6	6·864	40·43	8·019	47·24	9·042	53·26	9·971	58·74	6
9	8·544	113·2	9·971	132·2	11·236	148·9	12·384	164·1	9
12	9·971	234·9	11·630	274·0	13·100	308·7	14·434	340·1	12
15	11·236	413·7	13·100	482·3	14·750	543·0	16·248	598·2	15
18	12·384	656·5	14·437	765·4	16·248	861·4	17·895	948·7	18
21	13·444	970·1	15·664	1130·3	17·630	1272·2	19·413	1400·8	21
24	14·437	1360·7	16·813	1584·6	18·919	1783·1	20·831	1963·3	24
30	16·248	2392·7	18·919	2786 0	21·284	3134·2	23·429	3450·2	30
36	17·895	3794·8	20·831	4417·4	23·429	4968·3	25·786	5468·1	36

Diameter in inches.	Fall divided by Length of Pipe. $\frac{7}{100}$ Velocity in feet per second.	$\frac{7}{100}$ Discharge in cubic feet per minute.	$\frac{8}{100}$ Velocity in feet per second.	$\frac{8}{100}$ Discharge in cubic feet per minute.	$\frac{9}{100}$ Velocity in feet per second.	$\frac{9}{100}$ Discharge in cubic feet per minute.	$\frac{1}{10}$ Velocity in feet per second.	$\frac{1}{10}$ Discharge in cubic feet per minute.	Diameter in inches.
2	5·989	3·92	6·440	4·22	6·864	4·49	7·267	4·76	2
3	7·502	11·05	8·019	11·81	8·544	12·58	9·042	13·32	3
4	8·712	22·81	9·361	24·51	9·971	26·10	10·550	27·62	4
6	10·829	63·79	11·630	68·51	12·384	72·95	13·100	77·17	6
9	13·444	178·2	14·434	191·3	15·365	203·6	16·248	215·3	9
12	15·664	369·1	16·813	396·1	17·895	421·6	18·919	445·8	12
15	17·630	649·1	18·919	696·5	20·133	741·2	21·284	783·5	15
18	19·413	1029·2	20·831	1104·3	22·165	1175·1	23·429	1242·1	18
21	21·103	1522·8	22·584	1629·6	24·038	1734·6	25·407	1833·3	21
24	22·593	2129·3	24·238	2284·4	25·786	2430·3	27·252	2568·5	24
30	25·407	3741·5	27·252	4013·2	28·989	4269·0	30·634	4511·2	30
36	27·959	5928·9	29·986	6358·8	31·894	6763·4	33·702	7146·8	36

For EGG-SHAPED SEWERS, the diameter of whose large circle equals that of the Cylindrical Sewer; when flowing *one-half* full take $1\frac{1}{4}$, and when flowing *two-thirds* full take 2 of the above.

Surface and Mean Velocity of Rivers and Water Channels.

Let V_s = maximum surface velocity in feet per second

V = mean " "

$$C = \frac{V_s + 7 \cdot 78}{V_s + 10 \cdot 35}$$

Then

$$V = V_s \times C.$$

C = ·77	when V =	1	foot per sec.
·79	"	2	"
·81	"	3	"
·82	"	4	"
·83	"	5	"
·87	"	10	"

For large channels and moderate velocities Neville gives

$$V = \cdot 835\ V_s$$

Discharge of Water through Orifices.

A = Area of orifice in square feet.
H = Depth from surface of still water to centre of orifice in feet.
Q = Discharge in cubic feet per second.
V = Mean velocity in feet per second.

Then

$$V = C\sqrt{H}.$$
$$Q = AV.$$

$C = 4 \cdot 96$ for circular and square orifices in thin plates with sharp edges.

$= 4 \cdot 97$ rectangular ditto, when height $= \frac{\text{breadth}}{2}$

$= 5 \cdot 00$ ditto ditto, when height $= \frac{\text{breadth}}{4}$

$= 5 \cdot 60$ sluice at end of a rectangular channel.

$= 6 \cdot 50$ short tubes, whose length does not exceed 3 diameters, the edges square.

$= 5 \cdot 70$ ditto, when the tube projects into the cistern.

$= 8 \cdot 00$ ditto, when the edges of the tube are splayed so as to offer the least resistance.

In the foregoing the water in the reservoir is supposed to be kept at the same level, and the orifice placed below the surface at least 3 times its diameter or height, otherwise the head should be measured not from the centre of the orifice, but to the point where the mean velocity occurs, which is situated a little above the centre

When the water in the reservoir approaches the orifice with a velocity of its own $= V_a$, add to the head over the orifice that due to the velocity V_a.

$$H_a = \frac{V_a}{64 \cdot 4}$$

When the water is on both sides of an orifice, the effective head $= H$ will be the difference of level between the two surfaces.

Discharge over Notches and Weirs.

Let B = Breadth of notch or length of weir in feet.
H_a = Head due to velocity of approach in feet found as above.

H_b = Ditto over crest of weir or bottom of notch in feet, measured from level of still water.

Q = Discharge in cubic feet per second.

Then for a semicircular notch,

$$Q = \cdot 372\, A \sqrt{H_b + H_a}$$

Rectangular notch or weir,

$$Q = C\, B\, [(H_b + H_a)—H_a\, \tfrac{3}{2}]$$

When the water has no velocity of approach, omit H_a in both formulæ.

$C = 3\cdot 05 + \dfrac{H_b}{2\,B}$ for rectangular notches in flat vertical weir boards, provided $H\,b$ is equal to at least $\frac{1}{4}$th of breadth of notch.

$= 3\cdot 33$ weir with thin edge and B = full width of channel.

$= 2\cdot 67$ ditto, with broad flat crests on a rectangular notch, with small depth of water over the sill.

$= 3\cdot 33 \left(1 - \dfrac{H_b}{5\,B}\right)$ when the weir is contracted at both ends, i.e. does not extend the entire width of the channel.

$= 3\cdot 33 \left(1 - \dfrac{H_b}{10\,B}\right)$ when the weir is contracted at one end only, i.e. at one side of the channel.

TIME OF EMPTYING RESERVOIRS.

Rectangular—

$$\text{Time in seconds} = \frac{\text{contents in c. ft.} \times 2}{\text{discharge at outlet in c. ft. per sec.}}$$

Pyramidal or hopper-shaped, with outlet at the bottom—

$$\text{Time in seconds} = \frac{\text{contents in c. ft.} \times 6}{\text{disch. at outlet in c. ft. per sec.} \times 5}$$

Irregular-shaped ponds, &c.

Assume the water to be divided into horizontal laminæ, obtain the quantity of water in each, calculate the time of its discharge, with a head measured from the centre of each lamina to the centre of the orifice, then the sum of the times of discharge of each lamina will be the time of the total discharge.

THE PRESSURE OF WATER AGAINST WALLS, SIDES AND BOTTOMS OF CISTERNS, &c.

A = Area of surface pressed in feet.
H = Depth of centre of gravity below surface in feet.

Then $\quad$ Pressure in lbs. $= 62\frac{1}{2}$ A H.

The pressure may be considered as acting at a point $\frac{2}{3}$rds of the total depth from the top.

The pressure on the base of a vessel of any shape = the weight of a column of water having the same area as the base and the depth of the water for its height.

In a conical vessel standing on its base, the pressure on the base = 3 times the weight of the fluid.

In a hollow sphere the pressure on the surface of the lower semi-sphere = 3 times the weight of the fluid.

The pressure against the side of a pipe or other channel through which water is flowing equals the

effective head at that point less the head due to the velocity of the water.

To find the Force of Water impinging against a Plane Surface.

Force in lbs. = surface in square feet × velocity^2 in feet per second × C.

Values of C:

When surface of plane is at right angles or			90° = ·98
	”	”	80° = ·96
	”	”	70° = ·93
	”	”	60° = ·86
	”	”	50° = ·74
	”	”	40° = ·57
	”	”	30° = ·33
	”	”	20° = ·16
	”	”	10° = ·06

PUMPS.

The maximum effective height, measured from the surface of the water to the piston when at the top of its stroke, to which water will rise in the suction-pipe of a pump is *one foot* for every inch in height of the mercury in the barometer. This will be reduced according to the state of the pump and the velocity at which it is worked. In practice the maximum height should not exceed 25 feet.

In all pumps, whatever may be the diameter and inclination of the suction and delivery pipes, the weight to be lifted is equal to that of a column of water having for its base that of the piston, and for its height the difference of level between the surface of the water in the well and the point of delivery.

GAS SUPPLY.

Let d = Diameter of pipe in inches.
G = Specific gravity of gas.
L = Length of pipe in yards.
p = Initial pressure in inches.
Q = Quantity of gas in cubic feet per hour.
V = Velocity of the gas in feet per second.

$$V = \sqrt{\left(\frac{d\,p}{G\,L}\right)} \times 51 \left\{\begin{matrix}\text{for main pipes, or by} \\ \text{40 for service pipes}\end{matrix}\right\}$$

$$Q = M\sqrt{\left(\frac{d^5\,p}{G\,L}\right)}$$

$$d = C\sqrt[5]{\left(\frac{G\,L\,Q^2}{p}\right)}$$

Value of M for service pipes = 780
" main pipes = 1000

Some engineers take M as high as 1350 for all pipes, but except under very favourable circumstances it gives results much greater than would be safe to expect in practice.

Value of C for service pipes = ·073
" main pipes = ·063

The value of G for Newcastle coal ranges from ·4 to ·5, atmospheric air being 1. In calculations it may be assumed at ·45. For cannel coal it ranges from ·45 to ·7, and may be assumed in calculations at ·55.

To find the loss of pressure in inches of water while the gas is flowing through the pipe, due to friction only = p'.

$$p' = \frac{G\,L\,Q^2}{5\,d^5}$$

Q = Number of *thousand* cubic feet of gas per hour.

To find the pressure $= p''$ in inches of water required to maintain the velocity of the gas in the pipe—

$$p'' = \frac{V^2}{10000}$$

In practice the value of p'', except in very great velocities, seldom exceeds $\frac{1}{10}$th of an inch, in velocities up to 20 feet per second it may usually be neglected.

Every foot of rise or fall in a pipe increases or diminishes the initial pressure by $\frac{1}{100}$th of an inch of water.

The relative capacity of pipes for supplying gas varies as $d^{2\cdot5} = \sqrt{d^5}$

The produce from *one* ton of Newcastle coal after distillation is—

Gas	8000 to 10,000 cubic feet.
Coke	13 to 14 cwt.
Tar	10 gallons.
Ammoniacal liquor	13 ,,

About 5 cwt. of coke are required as fuel to carbonize 1 ton of coal.

The pressure at which gas is usually delivered into the pipes at the works is from $2\frac{1}{2}$ to 3 inches, with higher pressures the leakage from the mains becomes considerable.

Gas should be delivered into the branches for house supply at a pressure of 1 inch, from $\frac{3}{10}$ to $\frac{5}{10}$ being required at the burners (the latter pressure is the most economical); Cannel coal gas requires at least $\frac{1}{10}$th of an inch more pressure than that from ordinary Newcastle coal. About $\frac{2}{10}$ths of an inch pressure is required to work the meter, and the remainder to overcome the friction in the pipes.

The distribution of gas through branches seldom causes any loss of pressure in the main pipes beyond that due to friction and disturbance of the flow by the separation of the gas at the junctions, if the sizes of the former are properly proportioned.

Thickness of Main Pipes.—Cast-iron mains of 9 inches diameter and under should be about $\frac{3}{8}$ inch thick; between 9 and 18 inches, $\frac{1}{2}$ inch thick; and between 18 and 30 inches they should be $\frac{5}{8}$ inch thick.

Strength of Main Pipes.—All mains should be able to resist a pressure of at least 120 lbs. per square inch in order to ensure against leakage.

Siphons.—These should be placed at every depression in a pipe to receive the condensed liquid from the gas which should be allowed to drain into them, consequently in laying mains it is desirable to give them a slight rise or fall.

Service Pipes.—The diameters of service pipes to supply a given quantity of gas will depend on the length the number of bends, the elevation of the rooms to be lighted, &c. The following sizes are usual under the ordinary conditions of practice:

To supply	2 lights	requires a pipe	$\frac{1}{4}$	inch diameter.
,,	6	,,	$\frac{3}{8}$	,,
,,	12	,,	$\frac{1}{2}$	,,
,,	25	,,	$\frac{3}{4}$	,
,	50	,,	1	,,
,,	70	,,	$1\frac{1}{4}$	,,
,,	120	,,	$1\frac{1}{2}$	,,
,,	200	,,	2	,,

The sizes $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$ inch are generally used as branches to the burners. It is not desirable, however, to use in any case a pipe of smaller diameter

than $\frac{3}{8}$th of an inch; and for street lamps pipes $\frac{1}{2}$ in. in diameter should be used.

As gas flows with greater velocity at the higher levels, such as upper floors, &c., the diameters may be reduced accordingly.

To regulate the pressure in the higher levels, governors are usually placed at every 30 feet of elevation.

Wrought iron is the best for service pipes, particularly if galvanised; next composition metal, but brass pipes corrode rapidly.

All service pipes should commence with a long screw, to admit of the pipe being easily removed for repairs or additions.

In estimating for the supply of gas, allow 5 cubic feet per hour for each internal light, and 6 cubic feet for external lights; large or Argand burners require from 6 to 10 cubic feet per hour.

No light should be placed nearer to a lath and plaster ceiling than 3 feet without protection, nor nearer to woodwork on any side than 10 inches.

Gas pipes should be exposed where possible, and not let into the plaster of the wall.

NOTE.—Iron pipes are measured by their internal diameters, copper and brass pipes by their external diameters.

In large towns the average consumption of gas per head of the population per annum may be estimated at 2500 cubic feet, and in small towns at 2000 cubic feet.

Gas Service Pipes.

Supply in Cubic Feet per Hour.

Pressure = $\frac{1}{10}$ inch.

Length of Pipe in yds.	Diameter of Pipe in inches.					
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$
5	12·7	26·0	75·2	147·6	257·8	406·7
10	9·0	18·4	50·8	104·3	182·3	287·6
20	6·3	13·0	35·9	73·8	128·9	203·3
30	5·1	10·6	29·3	60·2	105·2	166·0
40	4·5	9·2	25·4	52·2	92·1	143·8
50	4·0	8·2	22·7	46·7	81·5	128·6
	Pressure = $\frac{2}{10}$ inch.					
5	18·0	36·9	101·7	208·7	364·6	575·1
10	12·7	26·1	71·9	147·6	257·8	406·7
20	9·0	18·5	50·8	104·0	182·3	287·6
30	7·4	15·1	41·5	85·2	148·8	234·8
40	6·4	13·0	35·9	73·8	128·9	203·3
50	5·7	11·7	32·2	66·0	115·3	181·9
	Pressure = $\frac{3}{10}$ inch.					
5	22·0	45·2	124·5	255·6	446·5	704·3
10	15·6	32·0	88·0	180·7	315·7	498·1
20	11·0	22·6	62·3	127·8	223·3	352·2
30	9·0	18·4	50·8	104·3	182·3	287·6
40	7·8	16·0	44·0	90·4	157·9	249·0
50	7·0	14·3	39·4	80·8	141·2	222·5
	Pressure = $\frac{4}{10}$ inch.					
5	25·5	52·2	143·8	295·1	515·6	813·3
10	18·0	36·9	101·7	208·7	364·6	575·1
20	12·7	26·1	71·9	147·6	257·8	406·7
30	10·4	21·3	58·7	120·5	210·5	332·0
40	9·0	18·5	50·8	104·0	182·3	287·6
50	8·0	16·5	45·5	93·3	163·0	257·2

Gas Service Pipes—*continued.*

Pressure = $\frac{5}{10}$ inch.

Length of Pipe in yds.	Diameter of Pipe in inches.					
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$
5	28·4	58·3	160·7	337·0	576·5	909·3
10	20·1	41·3	113·7	233·3	407·6	643·0
20	14·2	29·2	80·4	165·0	288·2	454·7
30	11·6	23·8	65·6	134·7	235·3	371·2
40	10·0	20·6	56·8	116·7	203·8	321·5
50	9·0	18·5	50·8	104·3	182·3	287·6
	Pressure = $\frac{6}{10}$ inch.					
5	31·1	63·9	176·1	361·5	631·5	996·1
10	22·1	45·2	124·5	255·6	446·5	704·3
20	15·6	32·0	88·0	180·7	315·7	498·1
30	12·7	26·1	71·9	147·6	257·8	406·7
40	11·0	22·6	62·3	127·8	223·3	351·2
50	9·8	20·2	55·7	114·3	199·7	315·0
	Pressure = $\frac{7}{10}$ inch.					
5	33·6	69·3	190·2	390·4	682·1	1076·0
10	23·8	49·0	134·4	275·8	482·3	757·4
20	16·8	34·5	95·1	195·2	341·0	538·0
30	13·7	28·2	77·7	159·4	278·5	439·3
40	11·9	24·4	67·3	138·0	241·2	380·4
50	10·6	21·8	60·1	123·5	215·7	340·2
	Pressure = $\frac{8}{10}$ inch.					
5	35·9	73·8	203·3	417·4	729·2	1150·2
10	25·5	52·2	143·8	295·1	515·6	813·3
20	18·0	36·9	101·7	208·7	364·6	575·1
30	14·7	30·1	83·0	170·4	297·7	469·6
40	12·7	26·1	71·9	147·6	257·8	406·7
50	11·4	23·3	64·3	132·0	229·7	363·7

GAS SERVICE PIPES—*continued.*

Pressure = $\frac{9}{10}$ inch.

Length of Pipe in yds.	Diameter of Pipe in inches.					
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$
5	38·1	78·3	215·7	442·8	773·4	1220·0
10	27·0	55·3	151·6	312·9	546 7	862·4
20	19·0	39·1	107·8	221·3	386·7	610·0
30	15·5	31 9	88·1	180·7	315·7	498·1
40	13·4	27·7	76·2	157·5	273·4	431·3
50	12·1	24·7	68·3	140·0	244·9	385·8
			Pressure = 1 inch.			
5	40·2	82·5	227·3	466·7	815·2	1286·0
10	28·4	58·3	160·7	337·0	576·5	909·3
20	20·1	41·3	113·7	233·3	407·6	643·0
30	16·4	33·7	92·8	190·5	332·8	525·0
40	14·2	29·2	80·4	165·0	288·2	454·7
50	12·7	26·1	71·9	147·6	257·8	406·7
			Pressure = $1\frac{1}{4}$ inch.			
5	44·5	91·9	253·3	520·0	908·4	1432·9
10	31·8	65·0	179·1	367·7	642·3	1012·3
20	22·5	46 0	126·7	260·0	454·2	716·5
30	18·3	37·5	103·4	212·3	370·9	585·0
40	15·8	32·5	89·6	183·8	321·2	506·6
50	14·2	29·1	80·1	164·4	287·3	453·1

NOTE.—The supply of gas, given in the foregoing Tables, is the net quantity at the burners based on actual results.

Gas Mains.—Supply in Cubic Feet per Hour.

Pressure = 1 inch.

Length of Pipe in yards.	Diameter of Pipe in inches.								
	2	2½	3	3½	4	4½	5	6	9	12
100	843	1473	2323	3416	4770	6404	8333	13145	36224	74361
250	533	932	1470	2161	3017	4050	5270	8314	22910	47030
500	377	659	1039	1528	2133	2864	3727	5879	16200	33255
1,000	267	466	735	1080	1509	2025	2635	4157	11455	23515
5,000	119	208	329	483	675	906	1179	1859	5123	10516
10,000	84	147	232	342	477	640	833	1315	3623	7436
					Pressure = 1¼ inch.					
100	943	1617	2598	3820	5333	7159	9317	14697	40500	83139
250	596	1042	1643	2416	3373	4528	5893	9295	25614	52581
500	422	737	1162	1708	2385	3202	4167	6573	18112	37181
1,000	298	521	822	1208	1687	2264	2946	4648	12807	26291
5,000	133	233	367	540	755	1013	1318	2079	5728	11758
10,000	94	165	260	382	533	716	932	1470	4050	8314
					Pressure = 1½ inch.					
100	1033	1804	2846	4184	5842	7843	10206	16100	44366	91074
250	653	1141	1800	2646	3695	6245	6455	10182	28059	57600
500	462	807	1273	1871	2613	3507	4564	7200	19841	40729
1,000	327	571	900	1323	1847	3122	3227	5091	14030	28800
5,000	146	255	402	470	826	1109	1443	2277	6274	12880
10,000	103	180	285	418	584	784	1021	1610	4437	9107

Gas Mains—*continued.*

Pressure = 1¾ inch.

Length of Pipe in yards.	Diameter of Pipe in inches.									
	2	2½	3	3½	4	4½	5	6	9	12
100	1116	1949	3074	4519	6311	8471	11024	17389	47920	98371
250	706	1233	1944	2858	3991	5358	6972	10998	30307	62215
500	499	872	1375	2021	2822	3788	4930	7777	21431	43993
1,000	353	616	972	1429	1996	2679	3486	5499	15154	31108
5,000	158	276	435	639	893	1198	1559	2459	6777	13912
10,000	112	195	307	452	631	847	1102	1739	4792	9837
					Pressure = 2 inches.					
100	1193	2082	3286	4831	6746	9056	11785	18590	51229	105162
250	754	1318	2078	3056	4267	5728	7454	11758	32400	66511
500	533	932	1470	2161	3017	4050	5270	8314	22910	47030
1,000	377	659	1039	1528	2133	2864	3727	5879	16200	33255
5,000	169	295	465	683	955	1281	1667	2629	7245	14872
10,000	119	208	329	483	675	906	1179	1859	5123	10516
					Pressure = 2½ inches.					
100	1333	2329	3674	5402	7542	10125	13176	20785	57276	117575
250	843	1473	2324	3416	4770	6404	8333	13145	36224	74361
500	596	1042	1643	2416	3373	4528	5893	9295	25614	52581
1,000	422	737	1162	1708	2385	3202	4167	6573	18112	37181
5,000	189	329	520	764	1067	1432	1863	29[illegible]9	8100	16628
10,000	133	233	367	540	754	1013	1318	2078	5728	11758

WALLS, &c.

Walls of Dwelling-Houses.

(Gwilt.)

$$\left.\begin{aligned} \text{Let } H &= \text{Height of wall.} \\ L &= \text{Length between party walls.} \\ D &= \text{Diagonal of face of wall.} \\ &= \sqrt{H^2 + L^2} \\ T &= \text{Thickness of walls.} \end{aligned}\right\} \text{All in feet.}$$

$$\text{Then } T = \frac{H\,L}{N\,D}$$

N = 22 for dwelling-houses of bricks.
20 for warehouses ditto.
18 for public buildings ditto.

When the height of the wall is less than half its length, the above constants may be increased to 27, 23, and 20 respectively.

The thickness of rubble stone walls to be $\frac{1}{3}$rd greater than those of brick.

The following Tables show the minimum thickness specified in the London Building Act, in accordance with which numerous houses have been erected from time to time.

Thickness of Walls of Dwelling-Houses.
Brick.

Ht up to 120 feet.	Length up to 45 feet. — One story, 30 in. Two stories, 26 in. Two stories, 21½ in. Three stories, 17½ in. Remainder, 13 in.	Length unlimited. — Top story, 13 in. Remainder, add 4½ in. for each story.
Ht. up to 100 feet.	Length up to 45 feet. — One story, 26 in. Two stories, 21½ in. Three stories, 17½ in. Remainder, 13 in.	Length unlimited. — One story, 30½ in. Two stories, 26 in. Two stories, 21½ in. Two stories, 17½ in. Remainder, 13 in.
Ht. up to 90 feet.	Length up to 45 feet. — One story, 26 in. One story, 21½ in. Three stories, 17½ in. Remainder. 13 in.	Length unlimited. — One story, 30½ in. Two stories. 26 in. One story, 21½ in. Two stories, 17½ in. Remainder, 13 in.
Ht. up to 80 feet.	Length up to 45 feet. — One story, 21½ in. Three stories, 17½ in. Remainder, 13 in.	Length unlimited. — One story, 26 in. Two stories, 21½ in. Two stories, 17½ in. Remainder, 13 in.
Ht up to 70 feet.	Length up to 45 feet. — One story, 21½ in. Two stories, 17½ in. Remainder, 13 in.	Length unlimited. — One story, 26 in. Two stories, 21½ in. One story, 17½ in. Remainder, 13 in.
Ht. up to 60 feet.	Length up to 45 feet. — Two stories, 17½ in. Remainder, 13 in.	Length unlimited. — One story, 21½ in. Two stories, 17½ in. Remainder, 13 in.

THICKNESS OF WALLS OF DWELLING-HOUSES—*contd.*

Ht. up to 50 feet.	Length up to 30 ft. — One story, 17½ in. Wall below the top story, 13 in. Remainder, 8½ in.	Length up to 45 ft. — Two stories, 17½ in. Remainder, 13 in.	Length unlimited. — One story, 21½ in. One story, 17½ in. Remainder, 13 in.
Ht. up to 40 feet.	Length up to 35 feet. — Wall below top story, 13 in. Top story, 8½ in.	Length unlimited. — One story, 17½ in. Rest of wall below top story, 13 in. Top story, 8½ in.	
Ht. up to 30 feet.	Length up to 35 feet. — Wall below two top stories, 13 in. Two top stories, 8½ in.	Length unlimited. — Wall below top story, 13 in. Top story, 8½ in.	
Ht. up to 25 feet.	Length up to 30 feet. — From base to top of wall, 8½ in.	Length unlimited. — Wall below top story, 13 in. Top story, 8½ in.	

THE THICKNESS OF WALLS FOR WAREHOUSES.
BRICK.

Maximum Height in feet.	Maximum Length in feet.	Thickness at Base in inches.	Maximum Length in feet.	Thickness at Base in inches.	Maximum Length in feet.	Thickness at Base in inches.
100	45	26	70	30	Length unlimited.	34
90	45	26	70	30		34
80	45	21½	60	26		30
70	45	21½	—	—		26
60	45	21½	—	—		26
50	30	17½	45	21½		26
40	35	13	45	17½		21½
30	45	13	—	—		17½
25	—	—	—	—		13

The thickness of the top 16 feet in height of warehouse walls to $= 13\frac{1}{2}$ inches, except where the entire height of the wall does not exceed 30 feet, in which case the topmost story may be 9 inches thick.

In case the foregoing Tables give a less proportion, the thickness to be increased to $\frac{1}{16}$th part of the height of the story for dwelling-houses, and to $\frac{1}{14}$th part for warehouses.

FOOTINGS to have a width at the base equal to *double* the thickness of the wall, diminishing in regular offsets, and to be in height equal to one-half the width at the base.

CROSS WALLS to be *two-thirds* of the thickness of the external or party walls, but never less than $8\frac{1}{2}$ inches.

ENCLOSURE WALLS.

Let f = The adhesive force per foot super. attained by the mortar or cement when thoroughly hardened.

H = Height in feet above ground.

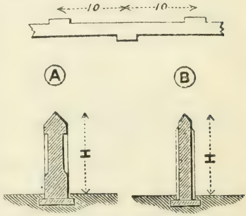
P = Pressure of wind in lbs. per foot super.

T = Thickness in feet of a wall with vertical faces and without buttresses.

W = Weight of wall in lbs. per cubic foot.

$$T = \sqrt{\frac{P H^2}{\frac{1}{3} f + H W}}$$

If P be taken at 40 lbs. to the square foot, it will be a sufficient allowance for safety in ordinary cases, as the wind rarely attains a great force so close to the ground, except in very exposed situations; in which case, or when the wall is of great length, it should be strengthened with buttresses placed about 10 feet apart, as sketch B; or the base may be increased in thickness, the quantity of masonry in the upper part of the wall being reduced by the formation of panels, as in sketch A.



Values of f = 6000 for brickwork in Portland cement and sand, 1 to 1.
= 5000 ditto, ditto, 1 to 2.
= 4000 ditto, ditto, 1 to 3.
= 4000 for brickwork in lias lime and sand, 1 to 2.
= 3600 ditto, grey chalk lime and sand, 1 to 2.
= 3000 ditto, ordinary lime and sand, 1 to 2.

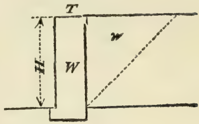
The value of f depends in some measure on the porosity of the material in the wall. For Portland and the softer stones, it may be taken equal to that of brick; but for the harder stones it should be reduced. This defect will, however, in most cases be more than compensated by the increased weight of the wall.

Value of W = 112 lbs. per cubic ft. for brickwork.
= 145 „ „ Portland and similar stones.
= 166 „ „ granite ditto.

Enclosure walls should have foundations at a sufficient depth in the ground to afford a firm foothold, and beyond the influence of frost. As the strength of walls of this class depends considerably on the strength of the mortar, the portion below the ground, if damp, and for at least 1 foot above it, should be built in hydraulic mortar or cement.

Retaining Walls.

T = The mean thickness of the wall.



H = The height.

w = The weight of a cubic foot of the earth at back in lbs.

W = Ditto of the wall.

Walls with vertical sides and the backing horizontal at top.

$$T = \cdot 7\ H \tan. \frac{a}{2} \sqrt{\frac{w}{W}}$$

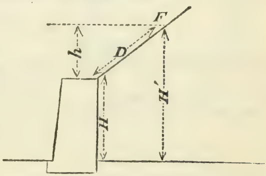
a being the angle which the natural slope of the earth makes with the vertical, as follows:

	a		$\tan. \frac{a}{2}$
Vegetable earth or clay in its natural state, consolidated and dry	= 45°	..	·414
Loamy ditto..	= 50°	..	·466
Gravel and sand, moist	= 52°	..	·488
Shingle or gravel without sand	= 54°	..	·510
Excavated earth, wet	= 56°	..	·532
Fine dry sand	= 58°	..	·554
London clay in its natural state, but saturated with water	= 65°	..	·637
Ditto, recently excavated, and ditto ..	= 75°	..	·767
Water	= 90°	..	1·000

Sloping Walls.

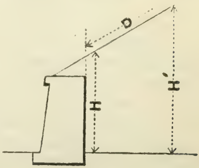
T = 1·00	wall with vertical sides.		
·86	„	external batter of	1 in 12.
·80	„	„	1 in 8.
·74	„	„	1 in 6.
·72	„	„	1 in 5.
·85	„	internal offsets and vertical face, but with $\frac{1}{7}$th less material than the vertical wall.	

Surcharged Revetments.



Substitute for H in the last formula the vertical height H′ measured to the point F, found by setting off the distance D = H along the slope of the bank.

When the bank is of less height above the wall than the distance H would give, take the actual height instead of H′ in the formula. This method, although not strictly correct, will be near enough for practice.



When the earth slopes from the front edge of the wall, H and D should be measured, as in sketch.

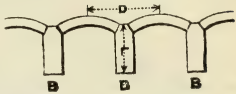
Revetments with Counterforts.

Walls of great length should have counterforts at the back about 20 feet apart. Their thickness and depth should equal the mean thickness of the wall.

The additional mean thickness of a wall without counterforts, which is equivalent to one that has them, may be found by *multiplying the length of the counterfort by its mean width, and dividing by the distance they are apart from centre to centre.*

The theoretical advantages of counterforts is small, but practically they are of considerable service in breaking the continuity of the earth in long lengths of backing; they also help to retain the earth by the friction against their sides.

Retaining walls are sometimes built with buttresses connected by horizontal arches, as in the sketch.

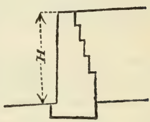


Rankine gives the following rule for the size of the buttresses:

$$L = T\sqrt{\frac{D}{B}}; \quad B = D\frac{T^2}{L^2}$$

T being the thickness required for a uniform wall to sustain the same bank of earth, B, D, and L being as shown in the diagram.

The diagram shows the section of wall usually adopted in practice when the backing is of earth. The thickness for a little more than one-third of the height from the base is made equal to $\frac{H}{3}$ and it is reduced towards the top in regular offsets at the back. The face is generally made to batter from about 1 in 6 to 1 in 10.



Too great a batter in a retaining wall is not desirable, as the wet gets into the joints and tends

to destroy the wall, unless they are pointed with cement. In walls built of bricks or other porous material, a batter is particularly objectionable on this account. All retaining walls which are backed with materials liable to become wet should be built in hydraulic mortar or Portland cement. If built in common mortar they should be increased in thickness.

Retaining walls should be well drained at the back, and have "weepholes" in the proportion of one to every four superficial yards of wall, to let the water escape.

NOTE.—It is to be observed that retaining walls backed with earth or clay, usually give way along a line which corresponds to that of the rupture of the backing and not by overturning as assumed by theory. The limits for the thickness are usually between $\frac{H}{4}$ and $\frac{H}{2}$; the former to resist earth in its most favourable condition, and the latter to resist fluids. It is by judgment and experience alone, that the engineer can adjust the thicknesses of his walls between these extremes.

ARCHES.

D = Thickness at crown.
H = Height of abutment to springing.
R = Radius of curvature at crown.
S = Span.
T = Thickness of abutment at springing.
V = Rise of arch to middle of depth at crown.

All in feet.

P = Horizontal thrust of half arch at springing in the same terms as adopted for the weight of the arch.

w = Weight of a cubic foot of the arch and its abutment.

W = Weight of half arch in same terms as w.

To find the depth at the crown.

$$D = C\sqrt{R}$$

$C = 0\cdot32$ hard granite
$= 0\cdot34$ „ sandstone
$= 0\cdot40$ „ brick
$= 0\cdot45$ rubble stone.

These values of C are for work built with Lias lime mortar; for brick or rubble stonework in best Portland cement they may be reduced. When the arch forms one of a series they should be slightly increased.

They also allow for the additional loads to which ordinary road and railway bridges are subject. For mere covering, arches having to sustain their own weight only, the values of C may be reduced by *one-third*; and for DOMES at the crown they may be reduced to *one-half*; but if necessary to resist crushing, the thickness of the latter should be increased towards the base.

The point of greatest pressure on the keystone may be assumed at *one-third* of its depth from the extrados, and on a voussoir at the springing at the same distance from the intrados.

NOTE.—The above formula originated with the present writer, see *Building News*, Feb. 27, 1857, where it was first published. It has since been adopted by several writers without acknowledgment.

For GOTHIC or pointed arches, take $\frac{2}{3}$ of C in the above formula, R being the radius by which the sides are struck.

Straight Arches with radiating joints.

$$D = C\sqrt{S} + \frac{S}{12}$$

NOTE.—An arch of 40° supporting more than its own weight is the flattest that can be constructed with safety when the depth at the crown does not exceed $C\sqrt{R}$.

Table of the Thickness required for the Crowns of Arches.

Radius of Curvature.	Granite Arches.	Sandstone Arches.	Brick Arches.	Radius of Curvature.	Granite Arches.	Sandstone Arches.	Brick Arches.
2	·45	·48	·56	16	1·28	1·36	1·60
$2\frac{1}{2}$	·51	·54	·63	17	1·32	1·40	1·65
3	·55	·59	·69	18	1·36	1·44	1·70
$3\frac{1}{2}$	·60	·64	·75	19	1·40	1·48	1·74
4	·64	·68	·80	20	1·43	1·52	1·79
$4\frac{1}{2}$	·68	·72	·85	22	1·50	1·60	1·88
5	·72	·76	·90	24	1·57	1·67	1·96
6	·78	·83	·98	26	1·63	1·73	2·00
7	·85	·90	1·06	28	1·69	1·80	2·12
8	·91	·96	1·13	30	1·75	1·86	2·19
9	·96	1·02	1·20	32	1·81	1·92	2·26
10	1·01	1·08	1·26	34	1·87	1·98	2·33
11	1·06	1·13	1·33	36	1·92	2·04	2·40
12	1·11	1·18	1·38	38	1·97	2·10	2·47
13	1·15	1·23	1·44	40	2·02	2·[illegible]5	2·53
14	1·20	1·27	1·50	45	2·15	2·28	2·68
15	1·24	1·32	1·55	50	2·26	2·40	2·83

To prevent an arch from bursting at the haunches, the space over the pier should be filled up solid to the level of the joint in the arch ring which makes with the horizontal an angle of 45°. After the centre is eased and before striking, the spandril walls should be carried up above the solid backing to a sufficient level.

Brick arches should be built in half-brick rings, with occasional bonding bricks or hoop iron in large arches, to prevent the rings from separating.

To find the thickness for the abutment.

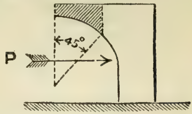
$$T = \sqrt{\frac{2\,P}{w} + \left(\frac{W}{w\,H}\right)^2} - \frac{W}{w\,H} + \frac{S}{10}$$

Which gives a thickness just sufficient to resist the thrust of the arch. In the case of railway and other arches liable to heavy moving loads, additional strength should be given to the abutments by means of wing walls, counterforts, or otherwise.

In very flat arches and those unduly loaded at the crown, the sliding of the arch on the abutment should be prevented by dowelling the courses near the springing, or by building the abutments in Portland cement, and allowing them to become thoroughly set before striking the centres.

To find the horizontal thrust.

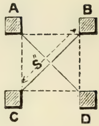
According to Rankine, P equals, roughly, the weight supported between the crown and that part of the soffit embraced by an angle of 45°; and when the arch contains less than 45°, P will equal the weight of the half arch and its load, multiplied by the cotangent of the inclination of the soffit to the horizon at the springing; or it may be found by multiplying the weight of the half arch by the horizontal distance of its centre of gravity from the springing, and dividing by the rise of the arch.



In GROINED arches, the horizontal thrust in the direction of the groin points equals nearly

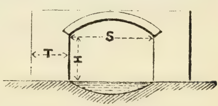
$$\frac{W'S'}{16\,V} = P$$

W′ being the weight of the whole arch between the piers A B C D, and S′ the diagonal in the direction A D or B C.



In arches where the height of the filling above them is considerable, as in those over door and window openings, the actual weight supported may be taken roughly as equal to the weight of the material included in the area of an equilateral triangle, the sides of which are equal to the span of the opening

The following Tables give the minimum thickness of abutment to resist the thrust of brick arches loaded, as sketch.



THICKNESS OF ABUTMENTS FOR ARCHES OF 120° CURVATURE.

Span of Arch.	Thickness at Crown.	Height of Abutment in feet.					
		5	7½	10	15	20	30
feet.	inches	feet.	feet.	feet.	feet.	feet.	feet.
5	9	2·02	2·15	2·20	2·30	2·40	2·42
6	9	2·18	2·36	2·44	2·57	2·68	2·75
7	9	2·35	2·57	2·68	2·84	2·96	3·04
8	9	2·51	2·78	2·82	3·11	3·24	3·33
9	9	2·68	2·99	3·16	3·38	3·52	3·63
10	14	2·84	3·20	3·40	3·65	3·80	3·94
12	14	3·16	3·55	3·84	4·17	4·34	4·50
14	14	3·48	3·95	4·27	4·68	4·87	5·05
16	14	3·80	4·10	4·70	5·12	5·40	5·60
18	14	4·10	4·70	5·05	5·65	6·00	6·36
20	18	4·40	5·00	5·40	6·10	6·60	7·10
25	18	5·00	5·67	6·10	6·90	7·55	8·40
30	18	5·52	6·25	6·80	7·70	8·50	9·39
35	23	6·04	6·80	7·50	8·50	9·40	10·67
40	23	6·56	7·45	8·20	9·30	10·30	11·93
45	23	7·08	8·06	8·93	10·23	11·30	12·83
50	23	7·59	8·68	9·65	11·16	12·30	13·74

The thickness of abutment for a SEMICIRCULAR arch may be taken from the above Table, by considering it as approximately equal to that for an arch of 120° having the same radius of curvature; therefore by dividing the span of the semicircular arch by 1·155 it will give the span of the 120° arch requiring the same thickness of abutment.

THICKNESS OF ABUTMENTS FOR ARCHES OF 60° CURVATURE

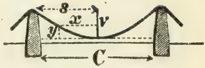
Span of Arch.	Thickness at Crown.	Height of Abutment in feet.					
		5	7½	10	15	20	30
feet.	inches.	feet.	feet.	feet	feet.	feet.	feet.
5	9	2·41	2·50	2·60	2·70	2·78	2·85
6	14	2·61	2·96	3·05	3·15	3·21	3·28
7	14	3·02	3·31	3·45	3·54	3·60	3·71
8	14	3·32	3·68	3·83	3·95	4·00	4·14
9	14	3·63	4·05	4·23	4·30	4·40	4·57
10	14	3·93	4·30	4·55	4·68	4·78	5·00
12	14	4·42	4·85	5·02	5·30	5·49	5·82
14	18	4·91	5·30	5·50	5·77	6·10	6·65
16	18	5·40	5·85	6·12	6·55	6·85	7·47
18	18	5·81	6·26	6·59	7·05	7·43	8·15
20	18	6·22	6·68	7·00	7·50	7·95	8·84
25	23	7·05	7·60	7·97	8·69	9·36	10·81
30	27	8·01	8·80	9·35	10·30	11·20	12·91
35	32	8·62	9·54	10·21	11·30	12·33	14·45
40	32	9·24	10·18	10·90	12·20	13·49	16·00
45	32	10·01	10·91	11·70	13·25	14·73	17·68
50	36	10·78	11·70	12·56	14·28	15·97	19·36

NOTE.—Groined arches are stronger than single ones of the same radius of curvature, although in some cases, from being imperfectly executed, the lower rings of the groin points are liable to fail, but without affecting the stability of the arch.

The material in the piers of groined arches should be calculated to resist the weight of at least *one-fourth* of the whole arch without crushing.

The centres of an arch should be carefully eased before striking, and the latter operation should be deferred until the mortar or cement becomes hard.

SUSPENSION BRIDGES, ETC.



C = Chord or span in feet.
L = Length of chain „
N = Number of suspending rods to each chain.

S = Half span = $\frac{C}{2}$ in feet.

T = Tension on chain at lowest part in tons.
T′ = Ditto at any distance = x in feet.
T″ = Ditto at head of pillar „
V = Versed sine or dip of curve „
W = Load distributed in tons supported by each chain.
w = Ditto on any tension rod.
x = Distance of any point in curve from centre in feet.
y = Height of x above bottom of chain at centre in feet.

$$L = 2\sqrt{S^2 + \tfrac{4}{3}V^2}$$

$$T = \frac{C\,W}{8\,V}$$

$$T' = T\sqrt{\left(\frac{2\,y}{x}\right)^2 + 1},$$

and T″ (at top of pillar) $= T\sqrt{\left(\frac{2\,V}{S}\right)^2 + 1}$

$$y = V\left(\frac{x}{S}\right)^2$$

$w = \frac{W}{N - 1}$ (weight of chain not to be included)

An elongation in inches = e of the chain due to temperature causes an increase of V in inches = $\frac{3\,C}{16\,V} \times e$.

The following table from the 'Aide-Mémoire' of the corps of Rl. Engrs. will be found useful.

V	T	T″.	L.	Increase in V due to an inch Elongation of Chain.
$\frac{C}{10}$	W × 1·25	W × 1·346	C × 1·0263	inches. 1·875
$\frac{C}{11}$	„ 1·375	„ 1·49	„ 1·022	2·0625
$\frac{C}{12}$	„ 1·5	„ 1·581	„ 1·0185	2·25
$\frac{C}{13}$	„ 1·625	„ 1·7	„ 1·0158	2·4375
$\frac{C}{14}$	„ 1·75	„ 1·82	„ 1·0136	2·65
$\frac{C}{15}$	„ 1·875	„ 1·94	„ 1·012	2·815

The Strength of Pipes.

$$\left.\begin{array}{l} d = \text{External diameter.} \\ d' = \text{Internal ditto.} \\ t = \text{Thickness of metal.} \end{array}\right\} \text{In inches.}$$

H = Head of water in feet.
P = Pressure in lbs. per square inch on d'.
f = Cohesive strength of the metal in lbs. per square inch.

For thin pipes.

$$t = \frac{d'\,P}{2\,f} = \frac{1 \cdot 16\,d'\,H}{f}$$

$$P = \frac{2\,f\,t}{d'}$$

$$H = \frac{f\,t}{1 \cdot 16\,d'}$$

For thick pipes. (Rankine.)

$$P = f\,\frac{d^2 - d'^2}{d^2 + d'^2}$$

$$\frac{d}{d'} = \sqrt{\left(\frac{f + P}{f - P}\right)}$$

$$\begin{aligned} f &= 44800 \text{ wrought iron.} \\ &= 15680 \text{ cast iron.} \\ &= 22400 \text{ copper.} \\ &= 17920 \text{ brass.} \\ &= 2800 \text{ lead.} \end{aligned}$$

The last formulæ, in which P is the bursting pressure, are applicable only to pipes of considerable thickness, such as the cylinder of the hydraulic press.

In practice the bursting pressure of gas and water pipes is not so much a point for consideration as the facility of casting, prevention of leakage, and strength to resist external pressure when laid in the ground. Therefore some engineers make the thickness of cast-iron pipes = $\frac{1}{5}\sqrt{\text{diam.}}$

Mr. Box gives the following for the *safe* head of water to which cast-iron pipes may be submitted:

$$t = \left(\frac{\sqrt{d'}}{10} + \cdot 15\right) + \left(\frac{H\,d'}{25000}\right)$$

NOTE.—Under a head of 578 feet = a pressure of 250 lbs. per square inch, water has been forced through the pores of cast-iron pipes of $\frac{5}{8}$ths to $\frac{3}{4}$ths of an inch in thickness.

The Hydraulic Press.

(Molesworth.)

d' = Internal diameter in inches.
P = Pressure in tons per square inch on the piston.
t = Thickness of metal in inches.

$$t = C\,d'\,P + 0{\cdot}5.$$

$$C = \begin{cases} \cdot 41 & \text{cast iron.} \\ \cdot 22 & \text{gun metal.} \\ \cdot 14 & \text{wrought iron.} \\ \cdot 06 & \text{steel.} \end{cases}$$

The bursting pressure may be found by the formula for thick pipes.

The *power* of the press will equal the force acting on the pump multiplied by the area of the piston of the cylinder, and divided by the area of the piston of the pump, less the friction, which may be estimated at from 0·5 to 1 per cent. of the power.

If the distance from the pump to the cylinder be great, the resistance due to the friction of the communication pipe must also be taken into account

Chimney Shafts.

The area of flue and height of shaft depend on the volume of air required for the combustion of the fuel, the temperature of the escaping gases, the resistance caused by friction and bends in the flue, all of which vary according to circumstances, and some of them cannot be estimated beforehand ; therefore it becomes necessary to adopt an empirical formula. The following has been found to answer in practice.

Let A = Area of flue at top in square feet.
d = Diameter of flue in inches.
F = Fuel in lbs. consumed per hour.

G = Feet super. of grate surface burning about 12 lbs. of coal per square foot per hour.

H = Vertical height of shaft above furnace bars in feet.

Then

$$A = C\frac{F}{\sqrt{H}} = 1\cdot25\frac{G}{\sqrt{H}}$$

$$d = 13\cdot54\sqrt{A}.$$

$$C = \cdot11 \text{ for ordinary bituminous coal.}$$

$$= \cdot09 \text{ coke and charcoal.}$$

$$= \cdot06 \text{ dry wood.}$$

For inferior coals the value of C should be increased.

NOTE.—The foregoing formula and constants include a length of horizontal flue not exceeding 100 feet from the furnace to the shaft; for greater lengths the area of the flue should be increased. If A' = the increased area in square feet and L = the length of flue from furnace to top of shaft, then approximately

$$A' = \cdot1313\, A\, L^{\frac{2}{5}}$$

A being the area found by the previous formula.

The height of the shaft above the ground is determined primarily by the necessity of producing a draught, and next by sanitary considerations. The following will be found in practice to meet both requirements.

Weight of Coal consumed per hour.	Height of Shaft.
100 lbs. and under	50 feet.
500 „ „	100 „
1000 „ „	120 „
2000 „ „	140 „
3000 „ „	160 „
4000 „ „	180 „
5000 „ and upwards	200 „

NOTE.—Shafts to carry off the gaseous products from chemical works should not be less than 250 feet in height. A shaft at the St. Rollox Chemical Works, Glasgow, erected in 1841, is 432 feet high and 40 feet external diameter at the base.

Proportions of Chimney Shafts.

$$\text{Exterior diameter at ground line} = \frac{H}{12}$$

The diameters of shafts over 300 feet high are sometimes made as small as $\frac{H}{14}$, in which case extra precautions are required to prevent the crushing of the lower portion of the brickwork and the shaft from being overturned by the force of the wind.

Thickness = t of the masonry at top.

When d is less than	48 inches,	$t =$	9 inches.
Ditto ,,	96 ,,	= 14	,,
Ditto above	96 ,,	= 18	,,

Thickness in inches of masonry at base of shaft = $\cdot 18\,H + t$.

In chimneys intended to receive air at a very high temperature, as those of reverberatory furnaces, fire-bricks must be employed, and the interstices filled in with fire-clay. In other cases ordinary bricks may be used, but it is always better to case the lower portion of the flue with fire-bricks.

Mortar is generally preferred to Portland cement in the erection of chimneys, as the latter does not stand the heat well unless mixed with a large proportion (40 per cent) of common salt, which, however, diminishes the strength.

The erection of tall chimney shafts should in all cases proceed slowly to allow of the mortar setting.

The best form of section for a chimney shaft, and which offers the least resistance to the wind, is the circle. In square flues, particularly if larger than required for the furnace, the cold air may find its way down the shaft by the corners, and diminish the draught by reducing the temperature.

It is calculated that every lb. of coals requires for its combustion from 275 to 300 cubic feet of air at a temperature of 32° Fahr., which is increased in bulk as it becomes heated in the furnace, usually 600° or 1000° Fahr.

Lightning Conductors.

The power of a conductor to transmit electricity varies directly as the sectional area, and inversely as the length.

The tension of electricity and tendency to leave a conductor varies inversely as the surface.

Authorities differ as to the relative conducting power of metals; the following will, however, be sufficiently near for practice:

Copper	100
Silver	99
Gold	80
Zinc	29
Platinum	18
Iron	17
Lead	8

The conducting power of water, according to Ganot, is many million times less than that of copper.

The quantity of material in a conductor should be in the inverse ratio of the conducting power.

In determining the proportions for different metals, the temperature at which they fuse should be taken into consideration.

Lightning conductors should be attached to the building which they are intended to protect, and placed in communication, when practicable, with all metals in the vicinity, particularly the eaves gutters and rain-water pipes. Joints should be avoided as much as possible.

At the base the conductors should be let into ground that is permanently wet, with which there should be about 6 superficial feet of metal in contact, or they should be connected with the gas and water mains in the street; should that be impracticable and the ground not sufficiently damp, a shallow trench of not less than 15 feet in length should be dug, and the lower part of the rod with some old chain or other iron connected thereto, laid along it and covered with powdered

charcoal or coal ashes. The drier the ground, the longer should be the trench.

The sectional area and number of conductors required for the protection of a building will in some measure depend on the length, distance apart, and nature of the ground in which they terminate; the drier the ground and the greater the distance apart, the larger should be the conductors.

The sizes for lightning conductors adopted in 1875 by the British Government for gunpowder magazines are as follows:

	Size.	Weight per foot run. lbs.
Copper rod	= $\frac{1}{2}''$ diam.	·757
„ bar	= $1\frac{1}{2}'' \times \frac{1}{8}''$	·723
„ tube	= $\frac{5}{8}''$ ext. diam. by $\frac{1}{8}''$ thick	·757
Iron rod ..	= $1''$ diam.	2·645
„ bar ..	= $2'' \times \frac{3}{8}''$	2·526

For dwelling houses and other buildings where the consequences would not be so great, the following sizes will in most cases be sufficient:

	Size.	Weight per foot run. lbs.
Copper rod	= $\frac{1}{4}''$ diam.	·189
Iron „	= $\frac{1}{2}''$ „	·661
„ tube	= $\frac{5}{8}''$ ext. diam. by $\frac{1}{8}''$ thick	·661

The Lightning Conductor Conference (1881) recommended as a *minimum* copper rod $\frac{3}{8}$ inch diameter. Iron ditto $\frac{9}{10}$th inch diameter, weighing respectively 7 and 35 ounces per lineal foot.

If the base of a lightning conductor is in free communication with the electric surface of the earth and all its joints are perfect, a large quantity of electricity passes upward from the top of the rod and tends to prevent or modify the discharge, and if the iron and other metals in a building be connected with the earth by a good conductor, a reservoir of electricity will often be formed in sufficient quantity to prevent disruption.

Conductors cannot be said to attract lightning, although they may determine its course. Any object that will reduce sufficiently the resistance of the space between the earth and clouds will cause a discharge.

A solid rod may be considered the best form for a conductor; a rope formed of thin wires is the most imperfect.

Painting iron rods is said not to interfere with their conductivity; on the other hand, galvanising adds to it, as well as affording protection against oxidation.

Electrical tests to prove the continuity of lightning conductors are of little value and are often misleading. A conductor of small dimensions, with well soldered joints, may be perfect in transmitting a charge of electricity of low potential, and yet be quite unsafe as a lightning conductor. Although it is desirable that the joints of conductors should be soldered to ensure absolute contact, a lightning discharge will readily bridge over an imperfect joint.

The War Department some years ago removed from their Powder Magazines the large conductors, erected under the direction of Sir Wm. Snow Harris in 1859, and substituted smaller ones with soldered joints.

WIND.

Let P = The pressure of the wind in lbs. per square foot against a surface perpendicular to its direction.

V = The velocity in miles per hour.

Then

$$P = \frac{V^2}{200}; \; V = \sqrt{200\,P}$$

NOTE.—Meteorologists consider these formulæ sufficiently near for practical purposes, but strictly P varies according to the weight of the air.

When the opposing surface is inclined, making an angle with the direction of the wind $= i$, we have, according to Hutton's experiments:

For the horizontal pressure $= P_h$ *or that* PARALLEL *to the direction of the wind,*

$$P_h = P \sin. i^{1\cdot842 \cos. i}$$

For the NORMAL *pressure* $= P_n$ *or that at right angles to the surface opposed to the wind,*

$$P_n = \frac{P_h}{\sin. i}$$

For the VERTICAL *pressure* $= P_v$ *or that at right angles to the direction of the wind,*

$$P_v = P \text{ cotan. } i. \sin. i^{\,1\cdot842 \cos. i}$$

TABLE SHOWING THE VALUES OF P_h, P_n, AND P_v, WHEN $P = 1$ LB. PER SQUARE FOOT.

Inclination of Surface $= i$.	P_h Parallel to Wind.	P_n Normal to Surface.	P_v Perpendicular to Wind.
°	lbs.	lbs.	lbs.
5	·011	·130	·130
10	·042	·240	·237
15	·090	·319	·337
20	·156	·456	·429
25	·232	·549	·498
27	·274	·603	·537
30	·331	·662	·574
35	·432	·754	·617
40	·536	·834	·639
45	·637	·900	·637
50	·730	·952	·612
55	·810	·968*	·567
60	·876	·980*	·506
65	·926	·987*	·432
70	·962	·993*	·350
75	·984	·996*	·264
80	·995	·998*	·175
85	·999	·999*	·087
90	1·000	·000	—

NOTE.—Owing to a slight irregularity in the results given by the formula, the figures marked * have been interpolated.

Table showing the Velocity and Pressure of Winds.

Designation.	Velocity in miles per hour. V.	Pressure in lbs. per square foot. P.
Scarcely perceptible	1	·005
Perceptible	2	·020
Slight breeze..	4	·080
Moderate ditto	8	·320
Fresh ditto	15	1·125
Brisk wind	25	3·125
Strong ditto	30	4·50
High ditto	40	8·00
Storm	50	12·50
Violent ditto..	60	18·00
Hurricane	80	32·00
Violent Hurricane	100	50·00
Gust observed at the Liverpool Observatory in 1868	126	80·00

Note.—In applying the foregoing formulæ and tables to calculations of the pressure of wind on roofs, it should be borne in mind that the velocity is considerably reduced in passing over obstacles on the earth's surface, also that it is probably modified in passing over roofs of low pitch by the current deflected upwards from the vertical face of the building. The author has occasionally observed during strong gusts of wind, instead of a pressure as assumed in some text-books, a slight vacuum which may have been produced from this cause.

Resistance offered by the wind to bodies having the same cross section but of various shapes (from Hutton's Experiments):

	Proportional numbers.
Cone, vertex towards the wind	126
Ditto, base to wind	291
Sphere	124
Cylinder, end to wind	285
Hemisphere, flat side	288
Ditto, round side	119

ANIMAL POWER.

MAN.

Duration of work = 1 day.

Description of Work.	Mean Effort in lbs.	Velocity in feet per minute.	Lbs. raised 1 foot high per min.
Lifting weights by hand breast high	40	25	1000
Raising water from a well by a bucket and rope	30	35	1050
Lifting a weight by a rope and overhead tackle	40	30	1200
Working a hand pump	30	60	1800
Drawing a canal boat	12	160	1920
Working a ship's capstan ..	25	100	2500
Turning the crank of a winch or crab	15	200	3000
Rowing a boat..	40	80	3200

NOTE.—The efforts in the above table, although extending over 8 to 10 hours, exclusive of meal-time, per day, are not altogether continuous, but include the usual intervals of rest or diminished exertion peculiar to each class of work.

Maximum efforts exerted for short periods of time:

Pushing a load horizontally	100 lbs.
Pulling ditto	70 „
Tractive force in dragging a cart or boat ..	40 „
Lifting a weight from the ground by the hands	150 „
Carrying on his shoulders at the rate of $2\frac{1}{2}$ miles per hour	120 „
Ditto by a porter or hawker accustomed to the work	180 „
Raising water 1 foot high per minute by a hand pump	300 gals.

NOTE.—The maximum energy which a man is capable of exerting during 24 hours, including period of rest, exclusive of that required to

maintain the phenomena of life (estimated at 600,000 foot pounds), is 1,700,000 lbs. raised 1 foot high = 2202 of Joule's 'Equivalents,' or an amount of heat capable of raising the temperature of 2202 lbs. of water 1 degree Fahr.

In tropical climates the work performed by Europeans cannot be estimated at more than 800,000 lbs. raised 1 foot high per day.

Horse.

Tractive force when working 8 hours per day on a well-made horizontal road and walking at the rate of $2\frac{1}{2}$ miles per hour	150 lbs.
Ditto working a lift or horse-run with intervals of rest between each movement, the day's work not to exceed 6 hours ..	300 "
Ditto walking in a circle of 30 feet diameter in working a mill for 8 hours per day at a pace of 2 miles per hour	100 "
He can exert a force horizontally at a dead pull of	400 "

If the power of a horse at a dead pull .. .. = 1·00
That of a mule .. .. .. = ·60
" an ass .. .. .. = ·25

A horse can carry on his back a distance of 20 miles per day on a well-made road, without over exertion .. from 250 to	300 lbs.
Elephant, ditto .. .. 800 "	1200 "
Camel, ditto .. .. 300 "	400 "
A mule, ditto	180 "
An ass, ditto	80 "

A *man* is usually supposed to be capable of exerting $\frac{1}{7}$th of the power of a horse when each is employed in the most advantageous manner.

The *Horse-power* adopted as the unit in estimating

the force of a steam engine is 33,000 lbs. raised 1 foot high per minute, an amount of work which few horses could perform for any length of time.

NOTE.—In estimating the tractive force of animals when travelling up inclined planes there should be added the weight of the load *plus* that of the animal multiplied by the ratio of the height of the plane to its length, also some quantity, which is difficult to estimate, for the loss of strength caused by the undue strain on the muscles and the increased exertion of the circulatory and respiratory organs.

FRICTION

Surfaces smooth, clean, and dry.

(Mean results.)

Substances.	Proportion of Pressure.	
	In Starting.	In Motion.
Wood on wood of the same kind, fibres of both parallel to axis of motion	·56	·45
Ditto on wood of a different kind, and ditto	·5	·4
Ditto on wood of the same kind, fibres of one at right angles to those of the other..	·45	·36
Stone on wood	·38	·3
Metals on wood	·4	·28
Metals on metals or stone	·23	·2
Stone on stone (both soft)	·7	·6
Ditto (both hard)	·5	·4
Brick on brick	·8	·67
Leather belts on hard-wood drums	—	·33
Ditto on iron or bronze	—	·5

NOTE.—When the surfaces are well lubricated with oil the friction during motion is rendered more uniform for all the substances mentioned in the above Table, and may be taken approximately at $\frac{1}{12}$th of the pressure.

Resistance to Sliding.

(Claudel.)

	Proportion of Weight.
Sandstone on sandstone, surface uniform and dry	·71
Ditto, ditto, with fresh mortar between ..	·66
Limestone on limestone, both hard and polished	·58
Ditto, ditto, the stone fine picked	·78
Granite, fine axed, on limestone, as last ..	·66
Ditto, ditto, with fresh mortar between ..	·49
Ashlar masonry on a bed of dry clay ..	·51
Ditto on moist clay	·34

To move a stone along a rough chiselled floor requires	$\frac{2}{3}$	of its weight.
Ditto on wood rollers 3 in. diameter	$\frac{1}{32}$	"
Ditto on a rough wooden floor ..	$\frac{3}{5}$	"
Ditto on wood rollers 3 in. diameter	$\frac{1}{40}$	"

Levers.

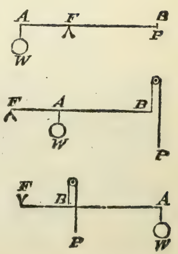
W = The weight to be raised.
P = The power.
F = The fulcrum.

$$P = \frac{W \times AF}{FB}$$

$$W = \frac{P \times FB}{AF}$$

$$FB = \frac{W \times AF}{P}$$

$$AF = \frac{P \times FB}{W}$$



Pulley.

N = Number of sheaves in the lower block.
P = The power required.
W = The weight to be raised.

$$P = \frac{W}{2\,N}$$

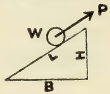
Inclined Plane.

P = The power.
W = The weight.
L = The length of the plane.
H = The height.
B = The base or horizontal length.

When the line of traction is parallel to L,

$$P = \frac{W\,H}{L}$$

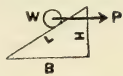
$$W = \frac{P\,L}{H}$$



When the line of traction is parallel to B,

$$P = \frac{W\,H}{B}$$

$$W = \frac{P\,B}{H}$$



The Screw.

The screw is similar to an inclined plane, the circumference being equal to B, and the distance apart of the threads equal to H. $L = \sqrt{B^2 + H^2}$.

When the screw is worked by a lever, as is

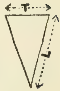
generally the case, if C = the circumference of the circle formed by the end of the lever and through which the power P acts, and d the pitch or distance between the centres of the threads, then

$$W = \frac{P\,C}{d}$$

Wedge.

When two substances are forced asunder by a *pressure* = P acting on the back of a wedge

$$\text{Force} = \frac{2\,L\,P}{T}$$



When only one of the substances is movable, the force exerted equals one-half of that when both are movable.

Note.—The thinner the wedge the greater is the force which it is capable of exerting. Wedges are generally driven by the percussive action of a hammer or ram, in which case there are no means of estimating the effect except by comparing the amount of work done with the velocity and weight of the hammer.

CRABS AND CRANES.

Let A, B, C, &c. = Diameters of the wheels.
a, b, c, &c. = " pinions.
D = " drum or barrel
H = " circle formed by the winch or handle.
P = Power applied to winch.
W = Weight to be raised.

Then

$$P = W\frac{D\,(a, b, c, \&c.)}{H\,(A, B, C, \&c.)}$$

$$W = P \frac{H\,(A, B, C, \&c.)}{D\,(a, b, c, \&c.)}$$

Allow 15 lbs. for each man turning the handle of a crab or crane, at a velocity of 200 feet per minute when the work is continuous, and 20 lbs. when there are intervals of rest.

Radius of crank	= from	15	to	18	inches.
Height of axle above ground..	= ,,	33	,,	36	,,
Pitch of first motion wheels ..	= ,,	$1\frac{1}{4}$	,,	$1\frac{1}{2}$	,,
Their width	= ,,	3	,,	4	,,
Pitch of second movers	= ,,	1	,,	$1\frac{1}{4}$	,,
Their width	= ,,	2	,,	3	,,

The pinion on the axle of the winch may have from 8 to 12 teeth.

The power of a crane may be increased by means of pulleys, and it is always desirable to use them when great loads are to be lifted, as they relieve the chain of a portion of the strain. The wharf crane shown by the annexed sketch has a single movable pulley, which doubles the power without increasing the stress on the chain, except that caused by the additional friction.

To calculate the stresses on cranes:

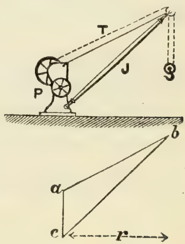
J = The compression on the stay or jib.
P = Ditto on the post.
T = The pull on the tension rod.
W = The load to be lifted, *plus* that due to the weight of the jib, chain, &c.

All in the same terms.

THE WHARF CRANE.

$$J = W \times \frac{b\,c}{a\,c}$$

$$T = W \times \frac{a\,b}{a\,c}$$



Or, if the vertical line $a\,c$ in the diagram be taken to represent the load W by scale, $a\,b$ and $b\,c$ measured by the

same scale will represent the stresses on the parts of the crane to which they are parallel. The force tending to break the post transversely is greatest at the foot of the jib, and its strength should be calculated as a beam of the length r (= the horizontal projection of the jib) fixed at one end and loaded at the other with a weight = the horizontal component of the thrust on the jib.

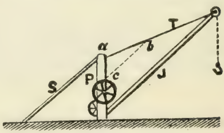
The horizontal stress at the foot of the post in the ground

$$= W \times \frac{r}{e}$$

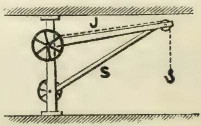
e being the length of the part below the surface of the ground.

The Derrick Crane.

The stresses on the tension rod, post, and jib may be found in the same manner as for the wharf crane.



In the derrick crane there are usually two back-stays, but as each may have to sustain the entire pull it should be calculated accordingly, as follows:—Set off $a\,b$ by scale equal the tension on T, and $b\,c$ drawn parallel to the back-stay will give the stress on it. The additional compression on the post caused by the back-stay will be represented by $a\,c$.



The Jib or Platform Crane.

In this crane the post is secured at the top and bottom, and the jib, which is

uppermost, is subject to tension, the stresses on which, as well as on the stay *s*, may be found as before, but the strength of the post may be found approximately as for a beam supported at both ends and loaded at an intermediate point, viz. the foot of the stay *s*, with a weight equal to the horizontal component of the thrust on the stay.

Other stresses may be induced, as, for instance, a transverse stress on the part of the jib that projects beyond the head of the stay, the strength to resist which should be calculated by the ordinary rules for transverse strength.

In the wharf and derrick crane, although the stress on the tension-rod T is relieved by the chain, it would not be safe to reduce the size of the former in consequence, as the chain may become foul or caught at the head of the jib in lowering the weight, and also because of the stiffness required to resist vibration due to the same cause.

Pile Driving.

Bearing Piles are chiefly used for foundations in order to transmit the weight of a structure through a yielding stratum to one that is unyielding; in other cases they are of doubtful utility.

There is no rule known by which to calculate the load a pile will support in soft ground, and it can only be estimated by the experience and judgment of the engineer.

The following empirical rule, given by Major Sanders of the American Engineers, is considered by English engineers to accord best with practice.

$$W = \frac{W' H}{8 H'}$$

W being the weight in tons that each pile will support with safety, W′ the weight of the ram in tons, H the fall of the ram in inches at the last stroke,

and H′ the distance in inches the pile has moved at the last stroke.

Piles should however be driven until a sufficient resistance is obtained. This was estimated to be the case by French engineers when the further penetration did not exceed $\frac{1}{5}$th of an inch with 30 blows from a ram of 800 lbs. weight falling from a height of 5 feet.

The best materials for bearing piles are beech and elm; fir and pine are, however, more frequently used.

The size varies from 9 to 18 inches square, according to the length; baulks of timber 12 to 13 inches square are most commonly used for large works.

The heads of piles should be bound with wrought-iron hoops to prevent them from splitting under the force of the ram.

The points should be shod with iron to preserve them from being broken by contact with stones or other hard substances.

The monkey, or ram, used varies in weight from 5 to 20 cwt., according to the size of the pile and resistance of the ground.

A light ram with a high fall is best for clay soils and a heavy ram with a low fall for sandy soils. A steam-hammer which gives rapid blows with a low fall is best for quick-sands. The writer has seen strong piles shivered to pieces when attempted to be driven through sand with a high fall.

2½ feet from centre to centre is the nearest distance apart at which piles can be driven with ease in clay soil.

1000 lbs. per square inch, in any case, is the maximum load that should be imposed on a soft wood pile, such as fir or pine.

When piles are surrounded by soft ground precautions should be taken against lateral yielding. This is best done by scooping out the ground between the heads of the piles for some feet in depth and filling the space up with concrete.

Sheeting Piles are usually made of deals or battens 9 to 12 inches wide and 3 to 6 inches thick; they are driven between guide piles and walings, and are used to enclose the space around a foundation on a yielding soil or to form a cofferdam. The lower end of the piles are bevelled and shod with iron. The bevelling is to cause the pile in driving to move towards the adjoining one and so assist in making a water-tight joint.

Linear Expansion by Heat from 32° to 212° Fahr.

White deal	1 part in	2450
Fire-brick	,,	2365
Marble	,,	2308
Brick, common	,,	1818
Brickwork in Portland cement and sand	,,	1655
Limestone (Caen)	,,	1322
Granite	,,	1267
Flint glass	,,	1248
White ditto	,,	1161
Platinum	,,	1131
Slate	,,	964
Portland cement (set)	,,	934
Steel, untempered	,,	927
Cast iron	,,	889
Mortar of Portland cement and sand	,,	848
Wrought iron	,,	819
Iron wire	,,	812
Steel, tempered	,,	807
Concrete of Portland cement and gravel	,,	700
Roman cement (set)	,,	697
Gold	,,	682
Gypsum	,,	602
Copper	,,	581
Brass	,,	532
Silver	,,	524
Tin	,,	460
Lead	,,	349
Zinc	,,	340

Note.—The superficial expansion is *double* and the cubic is *three* times the linear expansion.

Apparent Cubical Expansion of Liquids for each Degree Fahr. (in Glass Vessels).

Water.

Temp. Fahr.	Expansion.	Temp. Fahr.	Expansion.
40° to 42°	·0000129	122° to 132°	·000266
42 ,, 52	·0000486	132 ,, 142	·000287
52 ,, 62	·0000895	142 ,, 152	·000306
62 ,, 72	·0001216	152 ,, 162	·000323
72 ,, 82	·0001516	162 ,, 172	·000345
82 ,, 92	·0001758	172 ,, 182	·000360
92 ,, 102	·0002010	182 ,, 192	·000378
102 ,, 112	·0002239	192 ,, 202	·000396
112 ,, 122	·0002460	202 ,, 212	·000411

Other Liquids (Approximate).

Mercury	·0000857
Sulphuric and hydrochloric acids ..	·0003333
Oil of turpentine	·0003889
Fixed oils	·0004444
Nitric Acid	·0006111
Alcohol	·0006444

Note.—To find the absolute expansion add to the above the expansion of the glass = ·00001435.

Air and other Gases.

The cubical expansion for each degree of the thermometer, according to Regnault, is

Fahrenheit's scale = ·0020361
Centigrade scale = ·003665

Absolute zero below the freezing point of water.

On Fahrenheit's scale = 491·135
Centigrade scale = 272·9

Expansion of Water on Freezing.

Water attains its minimum bulk when the temperature = 39·1° Fahr., between which and 32° it expands by *cold*; at the latter temperature the increase = $\frac{1}{12}$th part of the bulk at 39·1°.

SHRINKAGE OF CASTINGS.

The pattern maker's rule should be for	Cast iron	$\frac{1}{8}$	of an inch	longer per lineal foot.
	Brass	$\frac{3}{16}$		
	Lead	$\frac{5}{16}$		
	Tin	$\frac{1}{4}$		
	Zinc	$\frac{5}{16}$		

THE FUSING TEMPERATURE OF METALS.

	Deg. Fahr.		Deg. Fahr.
Solder (Tinman's)	330	Silver, pure.. ..	1830
Tin	426	Copper	2050
Bismuth	493	Cast iron	2190
Lead	630	Gold, pure	2280
Zinc	800	Platinum ..	uncertain
Brass	1650	Wrought iron	uncertain

THE COMPARATIVE FACILITY AFFORDED BY BUILDING MATERIALS FOR TRANSMITTING HEAT.

Copper	1000	Glass	14
Iron	450	Brick, fire	13
Zinc	430	Ditto, common ..	12
Lead	230	Roman cement (set)	12
Marble, fine ..	54	Gypsum	11
Ditto, coarse ..	48	Lath and plaster..	10
Slate	42	Oak, perpendicular to the fibres ..	4
Bath stone, fine ..	27		
Ditto, coarse ..	25	Fir	3
Chalk	24	Cork	2
Asphalte	15	Canvas..	1

HEATING POWER OF FUEL.

Description.	Weight of Water heated 1° Fahr. by 1 lb. of Fuel.	Weight of Water at 212° Fahr. evaporated by 1 lb. of Fuel.
	lbs	lbs.
Welsh Coal	8685	9
Coke	8685	9
Newcastle Coal	8202	8½
Lancashire and Scotch ditto	7720	8
Wood (dry oak)	4342	4½
„ (dry pine)	2413	2½

Joule's EQUIVALENT equals the quantity of heat required to raise 1 lb. of water 1° Fahr., or a weight of 1 lb. to a height of 772 feet.

SOUND.

The velocity of sound through air increases with the temperature at the rate of about 1·0966 foot for each degree Fahr., as follows:

At 32° Fahr.	velocity	= 1093	feet per second.
40	„	= 1102	„
50	„	= 1113	„
60	„	= 1124	„
70	„	= 1135	„
80	„	= 1146	„
90	„	= 1156	„

Velocity through other substances:

Lead	4030	feet per second.
River water (55° Fahr.) ..	4714	„
Gold	5717	„
Silver	8553	„
Pine	10900	„

Velocity of Sound—continued.

Copper	11666	feet per second
Oak	12622	„
Ash	13314	„
Elm	13516	„
Fir	15218	„
Iron	16822	„

The intensity of sound is inversely as the square of the distance; it increases with the density of the air, and varies according to the direction of the wind.

Speaking Tubes.

The law of the intensity of sound transmitted through the open air does not apply to tubes. In the latter sound is transmitted to considerable distances with very little diminution of intensity.

The *velocity* of sound through tubes is nearly the same as through the open air.

Bends in a tube and roughness in the lining diminish the intensity of the sound. Properly constructed mouthpieces assist the voice in communicating through tubes.

Articulate sounds appear to be transmitted with greater facility through some metals than others. Pipes made of copper, alloys of lead and tin, and zinc, appear to transmit sound to greater distances than iron. Moisture in a pipe tends to confuse or annihilate articulate sounds.

A wrought-iron pipe 1 inch internal diameter with four quadrant bends, transmitted words distinctly when 250 feet long, but failed when 420 feet.

The writer has spoken through a wrought-iron pipe with two bends, 1⅛ inch internal diameter and 450 feet long, but failed to be heard when the pipe was lengthened to 600 feet. Lead pipe ¾ inch diameter can be used up to 250, and a tube of gutta-percha 1 inch diameter answered satisfactorily when

200 feet long. The lengths in the following table have been found safe for adoption in practice.

MAXIMUM EFFECTIVE LENGTH FOR SPEAKING TUBES.

Internal Diam.	Iron. Length.	Composition of Lead and Tin. Length.
½ in.	50 ft.	66 ft.
¾	120	160
1	220	280
1¼	280	350
1½	350	450

MISCELLANEOUS DATA.

Size of COACH HOUSE:—
- Depth .. .. 18 feet
- Height not less than .. .. 10 „
- Width of doorway .. .. 8 „

Size of COAL STORE:—
- For every ton of coals allow .. .. .. 45 cub. feet.

NOTE.—In the cellars of ordinary dwellings the height to which coals may be piled should be limited to 4 feet, and in coal-yards care should be taken to prevent a thrust against the walls unless they are of sufficient thickness. Doors and gates to coal stores should open outwards.

Size of COW HOUSES:—
- Average area of building for every cow.. 100 feet sup.
- Depth from wall to wall .. .. 18 feet.
- Height .. .. 10 „
- Width of *stalls* .. .. 5 „

CORN BARNS (for Thrashing, &c):—
- Size, exclusive of space for machinery .. 26 ft.×18 ft.
- Ditto of doorway .. .. 3½ ft.×7½ ft.

CATTLE SHEDS (Shelter only):—
- For every sheep allow floor-space .. .. = 10 ft. sup.
- „ pig „ „ .. .. = 10 „
- „ bullock, small „ .. .. = 40 „
- „ „ large „ .. .. = 60 „

CHURCHES:—
- Accommodation, including passages, communion table, &c., for every person .. 5 to 7 ft. sup.
- Width of *pews* .. .. 33 to 36 in.

CHURCHES—*continued.*

Length of *seats* for each person .. .. 18 to 24 in.
Height of ditto from floor .. .. 18 „
Width .. .. 13 to 15 „
Book-boards, height from floor .. .. .. 32 „
„ width .. .. 4½ „

NOTE.—The English Church Commissioners allow 20 inches by 34 inches for each sitting. For free sittings they allow 20 inches by 27 inches, and for children, 14 inches by 27 inches.

BALL ROOM:—

For each person allow as a minimum, exclusive of ante-rooms, &c. .. .. .. 16 feet sup.

ICE STORE:—

For every 112 lbs. of rough ice allow a a space of .. .. 6 cub. feet.

OVENS:—

For every bushel of bread allow a floor space of .. .. 7 feet sup.

STABLES:—

Accommodation, including *stalls*, passages, &c., for every horse allow .. .. .. 120 feet sup.
Width of building .. .. 18 feet.
viz.:—Hay-rack .. .. .. 2 feet.
Length of horse .. .. 8 „
Harness hanging loosely against wall .. .. 2 „
Gutter .. .. 1 „
Passage.. .. .. .. 5 „
Height from floor to ceiling .. .. .. 11 to 15 feet.
Stalls should not be less in width than.. 6 „
Loose boxes should equal in area two stalls.
Stable doors should be 4 feet by 7 feet high.

SCHOOL HOUSES:—

Best width for room .. .. 16 to 20 feet.
Height if ceiled at wall-plate .. .. .. 12 „
Ditto if floor space exceeds 360 feet sup.. 13 „
Ditto „ „ 600 „ .. 14 „
Height to wall-plate if ceiled to rafters and collar beam .. .. 11 „
Ditto from floor to collar beam.. .. .. 14 „
Distance of window-sills from floor.. .. 4 „
Benches should be, as a rule, 12 feet long; 18 inches to be allowed for each indi-

vidual of the junior classes and 22 inches for those of the senior classes.

The least distance apart from back to back of the desks should be .. .. 29 inches.

STAIRCASES :—

The proportions of tread and riser should be as in the following Table.

Width of Tread.	Height of Riser.	Width of Tread.	Height of Riser.
6 inches ..	.. $8\frac{1}{2}$ inches.	11 inches ..	.. 6 inches.
7 „ ..	.. 8 „	12 „ ..	.. $5\frac{1}{2}$ „
8 „ ..	.. $7\frac{1}{2}$ „	13 „ ..	.. 5 „
9 „ ..	.. 7 „	14 „ ..	.. $4\frac{1}{2}$ „
10 „ ..	.. $6\frac{1}{2}$ „	15 „ ..	.. 4 „

CENTRE OF GRAVITY.

If A denote a line joining the vertex and middle of the base or centre of any figure, D the distance of the centre of gravity from the vertex, and C the distance from the centre, we have

Plane Triangle .. .. $D = \frac{2}{3}A.$

Cone or Pyramid .. $D = \frac{3}{4}A.$

Parabola .. .. .. $D = \frac{3}{5}A.$

Semicircle .. .. .. $C = \cdot 42441\ A.$

Segment of Circle .. $C = \dfrac{\text{chord}^3}{12\ \text{area}}$

Sector of Circle .. .. $C = \dfrac{2\ \text{chord} \times \text{radius}}{3\ \text{length of arc}}$

Hemisphere .. .. $D = \frac{5}{8}A.$

Paraboloid .. .. .. $D = \frac{2}{3}A.$

Segment of Sphere .. $D = \dfrac{8\ \text{rad.} - 3\ \text{ver. sin.}}{12\ \text{rad.} - 4\ \text{ver. sin.}} \times \text{ver. sin.}$

Sector of Sphere .. $D = \dfrac{2\ \text{rad.} + 3\ \text{ver. sin.}}{8}$

Conic Frustum .. .. $D = \frac{1}{4} H \dfrac{3R^2 + 2Rr + r^2}{R^2 + Rr + r^2}$

D being the distance on the axis from the centre of the lesser end, H the height, and R r the radii of the greater and lesser ends.

THE WEIGHTS OF MATERIALS.

The weight of wrought iron × 0·928 = cast iron.
" " 0·928 = zinc.
" " 1·010 = steel.
" " 1·082 = brass.
" " 1·144 = copper.
" " 1·468 = lead.

THE WEIGHT OF WROUGHT-IRON BOLT HEADS, NUTS, AND WASHERS.

Diam. of Bolt.	Hexagon Heads and Nuts.	Square Heads and Nuts.	Round Washers.
inches.	per pair.	per pair.	per pair.
$\frac{1}{4}$	20 to a lb.	16 to a lb.	20 to a lb.
$\frac{3}{8}$	10 "	$8\frac{1}{3}$ "	10 "
$\frac{1}{2}$	5 "	$4\frac{1}{6}$ "	5 "
$\frac{5}{8}$	$2\frac{3}{4}$ "	$2\frac{1}{2}$ "	3 "
$\frac{3}{4}$	2 "	·56 lb.	·63 lb.
$\frac{7}{8}$	·77 lb.	·88	·77
1	1·25	1·31	1·25
$1\frac{1}{8}$	1·75	2·10	1·75
$1\frac{1}{4}$	2·13	2·56	2·25
$1\frac{3}{8}$	3·00	3·60	3·25
$1\frac{1}{2}$	3 75	4·42	4·25
$1\frac{5}{8}$	4·75	5·70	5·25
$1\frac{3}{4}$	5·75	7·00	6·50
$1\frac{7}{8}$	7·27	8·72	8·00
2	8·75	10·50	9 60
$2\frac{1}{2}$	17·00	21·00	19 00
3	28·80	36·40	32·50

ROUND AND SQUARE IRON.—WEIGHT OF A LINEAL FOOT.

Diam. or Side in inches.	Round in lbs.	Square in lbs.	Diam. or Side in inches.	Round in lbs.	Square in lbs.
$\frac{1}{8}$	·041	·053	$3\frac{5}{8}$	34·761	44·258
$\frac{1}{4}$	·165	·210	$3\frac{3}{4}$	37·199	47·363
$\frac{5}{16}$	·258	·329	$3\frac{7}{8}$	39·720	50·573
$\frac{3}{8}$	·372	·474	4	42·324	53·889
$\frac{7}{16}$	·506	·645	$4\frac{1}{8}$	45·011	57·310
$\frac{1}{2}$	·661	·842	$4\frac{1}{4}$	47·780	60·835
$\frac{9}{16}$	·837	1·066	$4\frac{3}{8}$	50·632	64·467
$\frac{5}{8}$	1·033	1·316	$4\frac{1}{2}$	53·567	68·203
$\frac{11}{16}$	1·250	1·592	$4\frac{5}{8}$	56·584	72·045
$\frac{3}{4}$	1·488	1·895	$4\frac{3}{4}$	59·684	75·992
$\frac{13}{16}$	1·746	2·223	$4\frac{7}{8}$	62·867	80·044
$\frac{7}{8}$	2·025	2·579	5	66·132	84·201
$\frac{15}{16}$	2·325	2·960	$5\frac{1}{8}$	69·480	88·464
1	2·645	3·368	$5\frac{1}{4}$	72·910	92·832
$1\frac{1}{8}$	3·348	4·263	$5\frac{3}{8}$	76·424	97·305
$1\frac{1}{4}$	4·133	5·263	$5\frac{1}{2}$	80·019	101·884
$1\frac{3}{8}$	5·001	6·368	$5\frac{5}{8}$	83·698	106·567
$1\frac{1}{2}$	5·952	7·578	$5\frac{3}{4}$	87·459	111·356
$1\frac{5}{8}$	6·985	8·894	$5\frac{7}{8}$	91·303	116·251
$1\frac{3}{4}$	8·101	10·315	6	95·230	121·250
$1\frac{7}{8}$	9·300	11·841	$6\frac{1}{4}$	103·331	131·565
2	10·581	13·472	$6\frac{1}{2}$	111·763	142·300
$2\frac{1}{8}$	11·945	15·209	$6\frac{3}{4}$	120·525	153·457
$2\frac{1}{4}$	13·392	17·051	7	129·618	165·035
$2\frac{3}{8}$	14·921	18·998	$7\frac{1}{2}$	148·796	189·453
$2\frac{1}{2}$	16·533	21·050	8	169·297	215·556
$2\frac{5}{8}$	18·228	23·208	$8\frac{1}{2}$	191·121	243·352
$2\frac{3}{4}$	20·205	25·471	9	214·267	272·812
$2\frac{7}{8}$	21·865	27·839	$9\frac{1}{2}$	238·736	303·967
3	23·807	30·312	10	264·527	336·806
$3\frac{1}{8}$	25·833	32·891	$10\frac{1}{2}$	291·641	371·328
$3\frac{1}{4}$	27·941	35·575	11	320·078	407·535
$3\frac{3}{8}$	30·131	38·364	$11\frac{1}{2}$	349·837	445·425
$3\frac{1}{2}$	32·405	41·259	12	380·919	485·000

FLAT BAR IRON.—WEIGHT OF A LINEAL FOOT.

Width in inches.	Thickness in inches.												Width in inches.
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.	
1/16	·0132	·0263	·0395	·0526	·0658	·0789	·0921	·1053	·1316	·1579	·1842	·2105	1/16
1/8	·0263	·0526	·0789	·1053	·1316	·1579	·1842	·2105	·2631	·3158	·3684	·4210	1/8
3/16	·0395	·0789	·1184	·1579	·1973	·2368	·2763	·3158	·3947	·4736	5526	·6315	3/16
1/4	·0526	·1053	·1579	·2105	·2631	·3158	·3684	·4210	·5263	·6315	·7368	·8420	1/4
5/16	·0658	·1316	·1973	·2631	·3289	·3947	·4605	·5263	·6578	·7894	·9210	1·053	5/16
3/8	·0789	·1579	·2368	·3158	·3947	·4736	·5526	·6315	·7894	·9473	1·105	1·263	3/8
7/16	·0921	·1842	·2763	·3684	·4605	·5526	·6447	·7368	·9210	1·105	1·289	1·474	7/16
1/2	·1053	·2105	·3158	·4210	·5263	·6315	·7368	·8420	1·053	1·263	1·474	1·684	1/2
9/16	·1184	·2368	·3552	·4736	·5920	·7104	·8289	·9473	1·184	1·421	1·658	1·895	9/16
5/8	·1316	·2631	3947	·5263	·6578	·7894	·9210	1·053	1·316	1·579	1·842	2·105	5/8
11/16	·1447	·2894	·4342	·5789	·7236	·8683	1·013	1·158	1·447	1·737	2·026	2·316	11/16
3/4	·1579	·3158	·4736	·6315	·7894	·9473	1·105	1·263	1·579	1·895	2·210	2·526	3/4
13/16	·1710	·3421	·5131	·6841	·8552	1·026	1·197	1·368	1·710	2·052	2·394	2·737	13/16
7/8	·1842	·3684	·5526	·7368	·9210	1·105	1·289	1·474	1·842	2·210	2·579	2·947	7/8
15/16	·1973	·3947	·5920	·7894	·9867	1·184	1·381	1·579	1·973	2·368	2·763	3·158	15/16

Flat Bar Iron—*continued.*

Width in inches	Thickness in inches.												Width in inches.
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
1	·210	·421	·632	·842	1·053	1·263	1·474	1·684	2·105	2·526	2·947	3·368	1
$1\frac{1}{8}$	·237	·474	·710	·947	1·184	1·421	1·658	1·895	2·368	2·842	3·315	3·789	$1\frac{1}{8}$
$1\frac{1}{4}$	·263	·526	·789	1·053	1·316	1·579	1·842	2·105	2·631	3·158	3·684	4·210	$1\frac{1}{4}$
$1\frac{3}{8}$	·289	·579	·868	1·158	1·447	1·737	2·026	2·316	2·894	3·473	4·052	4·631	$1\frac{3}{8}$
$1\frac{1}{2}$	·316	·632	·947	1·263	1·579	1·895	2·210	2·526	3·158	3·789	4·421	5·052	$1\frac{1}{2}$
$1\frac{5}{8}$	·342	·684	1·026	1·368	1·710	2·052	2·394	2·737	3·421	4·105	4·789	5·473	$1\frac{5}{8}$
$1\frac{3}{4}$	·368	·737	1·105	1·474	1·842	2·210	2·579	2·947	3·684	4·421	5·157	5·894	$1\frac{3}{4}$
$1\frac{7}{8}$	·395	·789	1·184	1·579	1·973	2·368	2·763	3·158	3·947	4·736	5·526	6·315	$1\frac{7}{8}$
2	·421	·842	1·263	1·684	2·105	2·526	2·947	3·368	4·210	5·052	5·894	6·736	2
$2\frac{1}{8}$	·447	·895	1·342	1·789	2·237	2·684	3·131	3·579	4·473	5·368	6·262	7·157	$2\frac{1}{8}$
$2\frac{1}{4}$	·474	·947	1·421	1·895	2·368	2·842	3·315	3·789	4·736	5·684	6·831	7·578	$2\frac{1}{4}$
$2\frac{3}{8}$	·500	1·000	1·500	2·000	2·500	3·000	3·500	4·000	4·999	5·999	6·999	7·999	$2\frac{3}{8}$
$2\frac{1}{2}$	·526	1·053	1·579	2·105	2·631	3·158	3·684	4·210	5·263	6·315	7·368	8·420	$2\frac{1}{2}$
$2\frac{5}{8}$	·553	1·105	1·658	2·210	2·763	3·315	3·868	4·421	5·526	6·631	7·736	8·841	$2\frac{5}{8}$
$2\frac{3}{4}$	·579	1·158	1·737	2·316	2·894	3·473	4·052	4·631	5·789	6·947	8·104	9 262	$2\frac{3}{4}$
$2\frac{7}{8}$	·605	1·210	1·816	2·421	3·026	3·631	4·236	4·842	6 052	7·262	8·473	9·683	$2\frac{7}{8}$

FLAT BAR IRON—*continued.*

Width in inches.	Thickness in inches.												Width in inches.
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
3	·632	1·263	1·895	2·526	3·158	3·789	4·421	5·052	6·315	7·578	8·841	10·104	3
3¼	·684	1·368	2·052	2·737	3·421	4·105	4·789	5·473	6·841	8·210	9·578	10·946	3¼
3½	·737	1·474	2·210	2·947	3·684	4·421	5·157	5·894	7·368	8·841	10·315	11·788	3½
3¾	·789	1·579	2·368	3·158	3·947	4·736	5·526	6·315	7·894	9·473	11·051	12·630	3¾
4	·842	1·684	2·526	3·368	4·210	5·052	5·894	6·736	8·420	10·104	11·788	13·472	4
4¼	·895	1·789	2·684	3·579	4·473	5·368	6·262	7·157	8·946	10·736	12·525	14·314	4¼
4½	·947	1·895	2·842	3·789	4·736	5·684	6 631	7·578	9 473	11·367	13 262	15·156	4½
4¾	1 000	2·000	3·000	4·000	4·999	5·999	6·999	7·999	9 999	11·999	13·998	15·998	4¾
5	1·053	2·105	3 158	4·210	5·263	6·315	7·368	8·420	10·525	12·630	14·735	16·840	5
5¼	1·105	2·210	3·315	4·421	5·526	6·631	7·736	8·841	11·051	13·262	15·472	17·682	5¼
5½	1·158	2·316	3·473	4 631	5·789	6·947	8·104	9·262	11·578	13·893	16·209	18·524	5½
5¾	1·210	2·421	3 631	4·842	6·052	7·262	8·473	9·683	12·104	14·525	16·946	19·366	5¾
6	1·263	2·526	3·789	5·052	6·315	7·578	8·841	10·104	12·630	15·156	17·682	20·208	6

Round, Octagonal, and Square Steel.—The Weight of a Lineal Foot.

Diameter of Circle and Oct. and Side of Square.	Round in lbs.	Octagonal in lbs.	Square in lbs.
$\frac{1}{8}$	·0417	·0440	·0532
$\frac{3}{16}$	·0940	·0991	·1196
$\frac{1}{4}$	·1670	·1762	·2127
$\frac{5}{16}$	·2610	·2753	·3323
$\frac{3}{8}$	·3758	·3964	·4785
$\frac{7}{16}$	·5115	·5396	·6513
$\frac{1}{2}$	·6681	·7047	·8507
$\frac{9}{16}$	·8456	·8919	1·077
$\frac{5}{8}$	1·044	1·101	1·329
$\frac{11}{16}$	1·263	1·332	1·608
$\frac{3}{4}$	1·503	1·586	1·914
$\frac{13}{16}$	1·764	1·861	2·246
$\frac{7}{8}$	2·046	2·158	2·605
$\frac{15}{16}$	2·349	2·478	2·991
1	2·673	2·819	3·403
$1\frac{1}{8}$	3·382	3·568	4·307
$1\frac{1}{4}$	4·176	4·405	5·317
$1\frac{3}{8}$	5·053	5·330	6·433
$1\frac{1}{2}$	6·013	6·343	7·656
$1\frac{5}{8}$	7·057	7·444	8·985
$1\frac{3}{4}$	8·185	8·633	10·421
$1\frac{7}{8}$	9·396	9·910	11·963
2	10·690	11·276	13·611
$2\frac{1}{4}$	13·530	14·271	17·227
$2\frac{1}{2}$	16·703	17·618	21·267
$2\frac{3}{4}$	20·211	21·318	25·734
3	24·053	25·371	30·625

Note.—The diameter of octagon steel is measured across the sides.

Flat Steel.—The Weight of a Lineal Foot.

Width in inches.	Thickness in inches.							
	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1/8	·0532	·1063	·1595	·2127	·2658	·3190	·3722	·4253
1/2	·2127	·4253	·6380	·8507	1·063	1·276	1·489	1·701
5/8	·2658	·5317	·7975	1·063	1·329	1·595	1·861	2·127
3/4	·3190	·6380	·9570	1·276	1·595	1·914	2·233	2·552
7/8	·3722	·7443	1·117	1·489	1·861	2·233	2·605	2·977
1	·4253	·8507	1·276	1·701	2·127	2·552	2·976	3·403
1 1/8	·4785	·9570	1·436	1·914	2·393	2·871	3·350	3·828
1 1/4	·5317	1·063	1·595	2·127	2·658	3·190	3·722	4·253
1 3/8	·5849	1·170	1·755	2·339	2·924	3·509	4·094	4·679
1 1/2	·6380	1·276	1·914	2·552	3·190	3·828	4·466	5·104
1 3/4	·7444	1·489	2·233	2·977	3·722	4·466	5·211	5·955
2	·8507	1·701	2·552	3·403	4·253	5·104	5·955	6·806
2 1/4	·9570	1·914	2·871	3·828	4·785	5·742	6·699	7·656
2 1/2	1·063	2·127	3·190	4·253	5·317	6·380	7·444	8·507
2 3/4	1·170	2·339	3·509	4·679	5·849	7·018	8·188	9·358
3	1·276	2·552	3·828	5·104	6·380	7·656	8·932	10·208
3 1/4	1·382	2·765	4·147	5·530	6·912	8·294	9·677	11·059
3 1/2	1·489	2·977	4·466	5·955	7·444	8·932	10·421	11·910
3 3/4	1·595	3·190	4·785	6·380	7·975	9·570	11·165	12·760
4	1·701	3·403	5·104	6·806	8·507	10·208	11·910	13·611
4 1/4	1·808	3·615	5·423	7·231	9·039	10·846	12·654	14·462
4 1/2	1·914	3·828	5·742	7·656	9·570	11·484	13·398	15·313
4 3/4	2 020	4·041	6·061	8·082	10·102	12·122	14·143	16·163
5	2·127	4·254	6·380	8·507	10·634	12·760	14·887	17·014
5 1/2	2·339	4·679	7·018	9·358	11·697	14·037	16·376	18·715
6	2·552	5·104	7·656	10·208	12·761	15·313	17·865	20·417

Round Cast Iron.—The Weight of a Lineal Foot.

Diam. in inches.	Weight in lbs.	Diam. in inches.	Weight in lbs.	Diam. in inches.	Weight in lbs.
1	2·454	5½	74·245	10	245·437
1¼	3·835	5¾	81·148	10¼	257·863
1½	5·522	6	88·357	10½	270·595
1¾	7·517	6¼	95·874	10¾	283·634
2	9·818	6½	103·697	11	296·979
2¼	12·425	6¾	111·827	11¼	310·632
2½	15·340	7	120·264	11½	324·591
2¾	18·561	7¼	129·008	11¾	338·857
3	22·089	7½	138·059	12	353·430
3¼	25·924	7¾	147·416	13	414·789
3½	30·066	8	157·080	14	481·057
3¾	34·515	8¼	167·051	15	552·234
4	39·270	8½	177·329	16	628·320
4¼	44·332	8¾	187·913	17	709·314
4½	49·701	9	198·804	18	795·217
4¾	55·377	9¼	210·002	20	981·750
5	61·359	9½	221·507	22	1187·917
5¼	67·649	9¾	233·319	24	1413·720

Round and Square Brass.—The Weight of a Lineal Foot.

Diam. or Side in in.	Round in lbs.	Square in lbs.	Diam. or Side in in.	Round in lbs.	Square in lbs.
$\frac{1}{16}$	·0112	·0142	$1\frac{5}{16}$	4·933	6·281
⅛	·0447	·0570	1⅜	5·414	6·893
$\frac{3}{16}$	·1012	·1282	$1\frac{7}{16}$	5·918	7·534
¼	·1790	·2279	1½	6·443	8·203
$\frac{5}{16}$	·2796	·3560	$1\frac{9}{16}$	6·991	8·901
⅜	·4047	·5127	1⅝	7·563	9·627
$\frac{7}{16}$	·5486	·6978	$1\frac{11}{16}$	8·155	10·382
½	·7159	·9115	1¾	8·789	11·165
$\frac{9}{16}$	·9060	1·154	$1\frac{13}{16}$	9·407	11·977
⅝	1·118	1·424	1⅞	10·117	12·817
$\frac{11}{16}$	1·353	1·723	$1\frac{15}{16}$	11·799	13·686
¾	1·611	2·051	2	11·454	14·583
$\frac{13}{16}$	1·891	2·407	2⅛	12·932	16·463
⅞	2·194	2·791	2¼	14·496	18·457
$\frac{15}{16}$	2·529	3·204	2⅜	16·152	20·565
1	2·863	3·646	2½	17·896	22·786
$1\frac{1}{16}$	3·233	4·116	2⅝	19·731	25·122
1⅛	3·624	4·614	2¾	21·655	27·572
$1\frac{3}{16}$	4·038	5·141	2⅞	23·670	30·135
1¼	4·474	5·697	3	25·771	32·813

COPPER BAR.—THE WEIGHT OF A LINEAL FOOT.

Diam. or Side in in.	Round in lbs.	Square in lbs.	Diam. or Side in in.	Round in lbs.	Square in lbs.
$\frac{1}{8}$	·047	·060	$1\frac{1}{2}$	6·811	8·672
$\frac{3}{16}$	·106	·135	$1\frac{9}{16}$	7·390	9·410
$\frac{1}{4}$	·189	·241	$1\frac{5}{8}$	7·993	10·177
$\frac{5}{16}$	·296	·376	$1\frac{3}{4}$	9·270	11·803
$\frac{3}{8}$	·426	·542	$1\frac{7}{8}$	10·642	13·550
$\frac{7}{16}$	·579	·738	2	12·108	15·417
$\frac{1}{2}$	·757	·964	$2\frac{1}{8}$	13·668	17·404
$\frac{9}{16}$	·958	1·219	$2\frac{1}{4}$	15·325	19·512
$\frac{5}{8}$	1·182	1·506	$2\frac{3}{8}$	17·075	21·740
$\frac{11}{16}$	1·431	1·822	$2\frac{1}{2}$	18·916	24·089
$\frac{3}{4}$	1·703	2·168	$2\frac{5}{8}$	20·856	26·558
$\frac{13}{16}$	1·998	2·544	$2\frac{3}{4}$	22·891	29·146
$\frac{7}{8}$	2·318	2·951	$2\frac{7}{8}$	25·019	31·856
$\frac{15}{16}$	2·661	3·387	3	27·244	34·688
1	3·027	3·854	$3\frac{1}{8}$	29·559	37·638
$1\frac{1}{16}$	3·417	4·351	$3\frac{1}{4}$	31·972	40·710
$1\frac{1}{8}$	3·831	4·878	$3\frac{3}{8}$	34·482	43·901
$1\frac{3}{16}$	4·269	5·435	$3\frac{1}{2}$	37·081	47·214
$1\frac{1}{4}$	4·730	6·022	$3\frac{5}{8}$	39·777	50·646
$1\frac{5}{16}$	5·214	6·634	$3\frac{3}{4}$	42·568	54·199
$1\frac{3}{8}$	5·723	7·287	$3\frac{7}{8}$	45·550	57·873
$1\frac{7}{16}$	6·255	7·964	4	48·433	61·667

CHAINS.—WEIGHT OF A LINEAL FOOT.

Diam. of Link in in.	Weight in lbs.	Diam. of Link in in.	Weight in lbs.	Diam. of Link in in.	Weight in lbs.
$\frac{1}{4}$	·63	$\frac{3}{4}$	5·33	$1\frac{1}{4}$	14·50
$\frac{5}{16}$	·91	$\frac{13}{16}$	6·16	$1\frac{5}{16}$	16·00
$\frac{3}{8}$	1·33	$\frac{7}{8}$	7·16	$1\frac{3}{8}$	17·66
$\frac{7}{16}$	1·50	$\frac{15}{16}$	8·16	$1\frac{1}{2}$	20·83
$\frac{1}{2}$	2·33	1	9·33	$1\frac{5}{8}$	24·17
$\frac{9}{16}$	3·00	$1\frac{1}{16}$	10·50	$1\frac{3}{4}$	28·33
$\frac{5}{8}$	3·67	$1\frac{1}{8}$	11·83	$1\frac{7}{8}$	32·50
$\frac{11}{16}$	4·50	$1\frac{3}{16}$	13·16	2	38·33

NOTE.—The Chains over 1 inch diameter are assumed to be made with studs.

Sheet Iron.—Weight of a Superficial Foot.

S.W. Gauge.	Dec. of an inch.	Weight in lbs.	S.W. Gauge.	Dec. of an inch.	Weight in lbs.
000	·372	15·035	20	·036	1·455
00	·348	14·065	21	·032	1·293
0	·324	13·095	22	·028	1·132
1	·300	12·125	23	·024	·970
2	·276	11·155	24	·022	·889
3	·252	10·185	25	·020	·808
4	·232	9·377	26	·018	·727
5	·212	8·468	27	·0164	·663
6	·192	7·760	28	·0148	·598
7	·176	7·113	29	·0136	·550
8	·160	6·467	30	·0124	·501
9	·144	5·820	31	·0116	·469
10	·128	5·173	32	·0108	·436
11	·116	4·688	33	·0100	·404
12	·104	4·203	34	·0092	·372
13	·092	3·718	35	·0084	·339
14	·080	3·233	36	·0076	·306
15	·072	2·910	37	·0068	·275
16	·064	2·587	38	·0060	·242
17	·056	2·263	39	·0052	·210
18	·048	1·940	40	·0048	·194
19	·040	1·617	41	·0044	·178

Hoop Iron.—Weight of 100 Lineal Feet.

S.W. Gauge.	Width in ins.	Weight in lbs.	S.W. Gauge.	Width in ins.	Weight in lbs.
11	3	117·304	15	1½	36·375
11	2¾	107·441	15	1⅜	33·344
12	2½	87·570	16	1¼	26·944
12	2	70·559	17	1⅛	21·219
13	2¼	69·714	18	1	16·167
13	2	61·972	19	⅞	11·789
13	1¾	54·226	20	¾	9·094
14	1¾	47·153	21	⅜	6·736
14	1½	40·417			

VARIOUS METALS.—THE WEIGHT OF A SUPERFICIAL FOOT.

Thickness in inches.	Wrought Iron.	Cast Iron.	Steel.	Copper.	Brass.	Lead.	Zinc.	Thickness in inches.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
$\frac{1}{16}$	2·526	2·344	2·552	2·891	2·734	3·708	2·344	$\frac{1}{16}$
$\frac{1}{8}$	5·052	4·687	5·104	5·781	5·469	7·417	4·687	$\frac{1}{8}$
$\frac{3}{16}$	7·578	7·031	7·656	8·672	8·203	11·125	7·031	$\frac{3}{16}$
$\frac{1}{4}$	10·104	9·375	10·208	11·563	10·938	14·833	9·375	$\frac{1}{4}$
$\frac{5}{16}$	12·630	11·719	12·760	14·453	13·672	18·542	11·719	$\frac{5}{16}$
$\frac{3}{8}$	15·156	14·062	15·312	17·344	16·406	22·250	14·062	$\frac{3}{8}$
$\frac{7}{16}$	17·682	16·406	17·865	20·234	19·141	25·958	16·406	$\frac{7}{16}$
$\frac{1}{2}$	20·208	18·750	20·417	23·125	21·875	29·667	18·750	$\frac{1}{2}$
$\frac{9}{16}$	22·734	21·094	22·969	26·016	24·609	33·375	21·094	$\frac{9}{16}$
$\frac{5}{8}$	25·260	23·437	25·521	28·906	27·344	37·083	23·437	$\frac{5}{8}$
$\frac{11}{16}$	27·786	25·781	28·073	31·797	30·078	40·792	25·781	$\frac{11}{16}$
$\frac{3}{4}$	30·312	28·125	30·625	34·688	32·813	44·500	28·125	$\frac{3}{4}$
$\frac{13}{16}$	32·839	30·469	33·177	37·578	35·547	48·208	30·469	$\frac{13}{16}$
$\frac{7}{8}$	35·365	32·812	35·729	40·469	38·281	51·917	32·812	$\frac{7}{8}$
$\frac{15}{16}$	37·891	35·156	38·281	43·359	41·016	55·625	35·156	$\frac{15}{16}$
1	40·417	37·500	40·833	46·250	43·750	59·333	37·500	1

Add for each side in GALVANIZED IRON ·096 lbs. per ft. sup.

Wrought-iron Pipes.—The Weight of a Lineal Foot.

Bore in inches.	Thickness of Metal in parts of an inch.								Bore in inches.
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	
	lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	
$\frac{1}{4}$	·208	·497	·869	1·324	1·861	2·481	3·184	3·969	$\frac{1}{4}$
$\frac{3}{8}$	·289	·661	1·116	1·653	2·273	2·976	3·761	4·629	$\frac{3}{8}$
$\frac{1}{2}$	·372	·827	1·364	1·984	2·687	3·472	4·340	5·291	$\frac{1}{2}$
$\frac{5}{8}$	·455	1·092	1·612	2·315	3·100	3·968	4·919	5·952	$\frac{5}{8}$
$\frac{3}{4}$	·537	1·157	1·860	2·645	3·513	4·464	5·497	6·613	$\frac{3}{4}$
$\frac{7}{8}$	·620	1·323	2·108	2·976	3·927	4·960	6·076	7·274	$\frac{7}{8}$
1	·703	1·488	2·356	3·307	4·340	5·456	6·654	7·936	1
$1\frac{1}{4}$	·868	1·819	2·852	3·968	5·167	6·448	7·812	9·258	$1\frac{1}{4}$
$1\frac{1}{2}$	1·033	2·149	3·348	4·629	5·993	7·440	8·969	10·581	$1\frac{1}{2}$
$1\frac{3}{4}$	1·199	2·480	3·844	5·291	6·820	8·432	10·126	11·904	$1\frac{3}{4}$
2	1·364	2·811	4·340	5·952	7·646	9·424	11·284	13·226	2
$2\frac{1}{4}$	1·529	3·131	4·836	6·613	8·473	10·416	12·441	14·549	$2\frac{1}{4}$
$2\frac{1}{2}$	1·695	3·472	5·332	7·274	9·300	11·403	13·598	15·872	$2\frac{1}{2}$
$2\frac{3}{4}$	1·860	3·803	5·828	7·936	10·126	12·400	14·756	17·194	$2\frac{3}{4}$
3	2·025	4·133	6·324	8·607	10·953	13·392	15·913	18·517	3

CAST-IRON PIPES.—THE WEIGHT OF A LINEAL FOOT.

Bore in inches.	Thickness of Metal in inches.										Bore in inches.
	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1½	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
2	5·522	8·744	12·272	16·107	20·249	24·697	29·452	34·515	39·884	51·542	2
2¼	6·136	9·664	13·499	17·641	22·089	26·845	31·907	37·276	42·952	55·223	2¼
2½	6·750	10·584	14·726	19·175	23·950	28·992	34·361	40·037	46·019	58·905	2½
2¾	7·363	11·505	15·953	20·709	25·771	31·140	36·816	42·798	49·087	62·587	2¾
3	7·977	12·425	17·181	22·243	27·612	32·287	39·270	45·559	52·155	66·268	3
3¼	8·590	13·346	18·408	23·777	29·452	35·435	41·724	48·320	55·223	69·950	3¼
3½	9·204	14·266	19·635	25·311	31·293	37·583	44·179	51·082	58·291	73·631	3½
3¾	9·817	15·186	20·862	26·845	33·134	39·730	46·633	53·843	61·359	77·313	3¾
4	10·431	16·109	22·089	28·379	34·975	41·878	49·087	56·604	64·427	80·994	4
4¼	11·045	17·027	23·317	29·913	36·816	44·025	51·542	59·365	67·495	84·676	4¼
4½	11·658	17·948	24·544	31·447	38·656	46·177	53·996	62·126	70·563	88·357	4½
4¾	12·272	18·868	25·771	32·981	40·497	48·320	56·451	64·888	73·631	92·039	4¾

CAST-IRON PIPES—*continued.*

Bore in inches.	Thickness of Metal in inches. ¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1½	Bore in inches.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
5	12·885	19·788	26·998	34·515	42·338	50·468	58·905	67·649	76·699	95·721	5
5½	14·113	21·629	29·452	37·583	46·020	54·763	63·814	73·171	82·835	103·084	5½
6	15·340	23·470	31·908	40·651	49·701	59·058	68·722	78·693	88·971	110·447	6
6½	16·567	25·311	34·361	43·719	53·383	63·354	73·631	84·216	95·107	117·810	6½
7	17·794	27·152	36·816	46·787	57·064	67·649	78·540	89·738	101·243	125·173	7
7½	19·021	28·992	39·270	49·854	60·746	71·944	83·449	95·260	107·379	132·536	7½
8	20·249	30·833	41·724	52·922	64·427	76·239	88·357	100·783	113·515	139·899	8
8½	21·476	32·674	44·179	55·990	68·109	80·534	93·266	106·305	119·651	147·262	8½
9	22·703	34·515	46·633	59·058	71·790	84·829	98·175	111·827	125·787	154·626	9
9½	23·930	36·355	49·087	62·126	75·472	89·124	103·084	117·350	131·923	161·989	9½
10	25·157	38·196	51·541	65·194	79·154	93·420	107·992	122·872	138·059	169·352	10
10½	26·385	40·037	53·996	68·262	82·835	97·715	112·901	128·394	144·195	176·715	10½
11	27·612	41·878	56·451	71·330	86·517	102·010	117·810	133·917	150·330	184·078	11
12	30·066	45·559	61·359	77·466	93·880	110·600	127·627	144·962	162·602	198·804	12
13	32·520	49·241	66·268	83·602	101·243	119·191	137·445	156·006	174·874	213·531	13
14	34·975	52·922	71·177	89·738	108·606	127·781	147·262	167·051	187·146	228·257	14

Cast-iron Pipes—*continued.*

Bore in inches.	Thickness of Metal in inches.									Bore in inches.
	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{2}$	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
15	56·604	76·086	95·874	115·969	136·371	157·080	178·096	199·418	242·983	15
16	60·286	80·994	102·010	123·332	144·962	166·897	189·140	211·690	257·709	16
17	63·967	85·903	108·146	130·695	153·552	176·715	200·185	223·962	272·436	17
18	67·649	90·812	114·282	138·059	162·142	186·532	211·230	236·234	287·162	18
19	..	95·721	120·418	145·422	170·732	196·350	221·273	248·505	301·888	19
20	..	100·629	126·554	152·785	179·323	206·167	233·319	260·777	316·614	20
21	..	105·538	132·690	160·148	187·913	215·985	244·364	273·049	331·341	21
22	..	110·447	138·826	167·511	196·503	225·802	255·408	285·321	346·067	22
23	..	115·356	144·962	174·874	205·094	235·620	266·453	297·593	360·793	23
24	..	120·264	151·097	182·237	213·684	245·437	277·498	309·865	375·519	24
25	..	125·173	157·233	189·600	222·274	255·255	288·542	322·137	390·246	25
26	..	130·082	163·369	196·964	230·865	265·072	299·587	334·409	404·972	26
27	..	134·991	169·505	204·327	239·455	274·890	310·632	346·680	419·698	27
28	..	139·899	175·641	211·690	248·045	284·707	321·677	358·952	434·424	28
29	..	144·808	181·776	219·053	256·636	294·525	332·721	371·224	449·151	29
30	..	149·717	187·913	226·416	265·226	304·342	343·766	383·496	463·877	30

Note.—For each joint add the weight of a foot in length of the pipe.

WEIGHT OF CAST-IRON SOCKET PIPES.

For a Head of Water = 300 feet and under.

Bore.	Length when Laid.	Length of Socket.	Thickness of Metal.	Weight of each pipe.	Size of Lead Joint.	Weight of Lead Joint.
inches.	ft. in.	inches.	inches.	lbs.	inches.	lbs.
1½	6 0	3	¼	30	1½ × ¼	1·2
2	"	"	5/16	51	"	1·4
2½	"	3¼	"	62	"	1·6
3	9 0	3½	⅜	121	1¾ × ¼	2·3
3½	"	"	"	137	"	2·8
4	"	4	"	157	2 × 5/16	4·0
4½	"	"	7/16	210	"	4·5
5	"	"	"	233	"	5·0
6	"	4¼	½	314	2¼ × 5/16	6·5
7	"	"	"	359	"	7·7
8	"	"	"	408	"	8·2
9	"	4½	9/16	527	2½ × 5/16	10·4
10	"	"	"	573	"	11·5
11	"	"	"	672	"	14·9
12	"	"	⅝	755	2¾ × ⅜	18·2
13	"	"	"	824	"	19·6
14	"	"	"	882	"	20·8
15	"	"	"	948	"	22·2
16	"	"	¾	1217	"	23·8
17	"	"	"	1289	"	25·2
18	"	"	"	1365	"	26·6
19	"	"	"	1452	"	27·9
20	"	"	⅞	1794	"	29·6
22	"	"	"	1964	"	32·3
24	"	"	"	2136	"	35·0

Table of the Weight of Cast-Iron Flanged Pipes in Nine Feet Lengths.
(Nystrom.)

Bore in in.	Thickness of Metal.	Diameter of Flanges.	Thickness of Flanges.	Diameter of Circle through Holes.	Diameter and Number of Holes.		Weight per Pipe.		
	inch.	inches.	inch.	inches.	in.	No.	cwt.	qrs.	lbs.
2	$\frac{3}{8}$	$6\frac{1}{2}$	$\frac{9}{16}$	$4\frac{3}{4}$	$\frac{5}{8}$	4	0	3	0
3	$\frac{3}{8}$	$7\frac{1}{2}$	$\frac{5}{8}$	6	$\frac{5}{8}$	4	1	0	3
4	$\frac{1}{2}$	$9\frac{1}{2}$	$\frac{3}{4}$	$7\frac{3}{4}$	$\frac{3}{4}$	4	1	3	5
5	$\frac{1}{2}$	$10\frac{1}{2}$	$\frac{7}{8}$	$8\frac{3}{4}$	$\frac{3}{4}$	4	2	1	12
6	$\frac{5}{8}$	12	$\frac{7}{8}$	10	$\frac{7}{8}$	4	3	2	1
7	$\frac{5}{8}$	14	1	$11\frac{3}{4}$	1	6	4	3	17
8	$\frac{3}{4}$	15	1	$12\frac{3}{4}$	1	6	5	2	9
9	$\frac{3}{4}$	$16\frac{1}{2}$	$1\frac{1}{16}$	$14\frac{1}{4}$	1	6	6	1	12
10	$\frac{3}{4}$	$17\frac{1}{2}$	$1\frac{1}{8}$	$15\frac{1}{2}$	1	6	7	0	0
11	$\frac{7}{8}$	19	$1\frac{3}{16}$	$16\frac{3}{4}$	1	6	8	3	24
12	$\frac{7}{8}$	20	$1\frac{1}{4}$	$17\frac{3}{4}$	$1\frac{1}{8}$	6	9	3	5
13	$\frac{7}{8}$	21	$1\frac{1}{4}$	$18\frac{3}{4}$	$1\frac{1}{8}$	6	10	2	0
14	$\frac{7}{8}$	22	$1\frac{1}{4}$	$19\frac{3}{4}$	$1\frac{1}{8}$	8	11	0	26
15	$\frac{7}{8}$	23	$1\frac{1}{4}$	$20\frac{3}{4}$	$1\frac{1}{8}$	8	12	0	25
16	$\frac{7}{8}$	$24\frac{1}{2}$	$1\frac{5}{16}$	22	$1\frac{1}{4}$	8	12	3	8
17	$\frac{7}{8}$	$25\frac{1}{2}$	$1\frac{5}{16}$	23	$1\frac{1}{4}$	8	13	2	17
18	1	$26\frac{1}{2}$	$1\frac{3}{8}$	24	$1\frac{1}{4}$	8	16	1	15
19	1	28	$1\frac{3}{8}$	25	$1\frac{3}{8}$	8	17	2	13
20	1	29	$1\frac{3}{8}$	26	$1\frac{3}{8}$	8	18	0	26

Note.—Indiarubber rings form the best packing for the joints of flange pipes.

Copper Pipes.—The Weight of a Lineal Foot.

Bore in inches.	Thickness of Metal in parts of an inch.							
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{3}{16}$	·189	·473	·851	1·324	1·892	2·554	3·311	4·162
$\frac{1}{4}$	·236	·568	·993	1·514	2·128	2·838	3·642	4·541
$\frac{5}{16}$	·284	·662	1·135	1·703	2·365	3·121	3·973	4·918
$\frac{3}{8}$	·331	·757	1·277	1·892	2·601	3·406	4·304	5·297
$\frac{7}{16}$	·378	·851	1·419	2·081	2·838	3·689	4·635	5·675
$\frac{1}{2}$	·426	·946	1·561	2·270	3·075	3·973	4·966	6·054
$\frac{9}{16}$	·473	1·040	1·703	2·459	3·311	4·256	5·297	6·432
$\frac{5}{8}$	·520	1·185	1·845	2·649	3·547	4·540	5·629	6·811
$\frac{11}{16}$	·568	1·230	1·986	2·838	3·783	4·824	5·959	7·190
$\frac{3}{4}$	·615	1·324	2·129	3·027	4·020	5·108	6·290	7·568
$\frac{13}{16}$	·662	1·419	2·271	3·216	4·257	5·592	6·622	7·946
$\frac{7}{8}$	·709	1·514	2·412	3·405	4·493	5·676	6·953	8·324
$\frac{15}{16}$	·757	1·608	2·554	3·594	4·729	5·960	7·284	8·703
1	·804	1·703	2·696	3·784	4·966	6·243	7·615	9·081
$1\frac{1}{4}$	·993	2·081	3·263	4·540	5·912	7·378	8·938	10·595
$1\frac{1}{2}$	1·182	2·459	3·831	5·297	6·857	8·514	10·264	12·105
$1\frac{3}{4}$	1·372	2·838	4·398	6·055	7·805	9·646	11·586	13·621
2	1·560	3·217	4·967	6·808	8·748	10·783	12·911	15·135
$2\frac{1}{4}$	1·750	3·591	5·531	7·566	9·694	11·918	14·234	16·647
$2\frac{1}{2}$	1·940	3·975	6·103	8·327	10·643	13·066	15·565	18·165
$2\frac{3}{4}$	2·128	4·352	6·668	9·081	11·590	14·190	16·886	19·677
3	2·316	4·729	7·238	9·737	12·534	15·325	18·212	21·190

Weight per foot run in lbs. $= 3{\cdot}027\ (D^2 - D'^2)$, D and D′ being the external and internal diameter in inches.

BRASS PIPES.—THE WEIGHT OF A LINEAL FOOT.

Bore in inches.	Thickness of Metal in parts of an inch.							
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{3}{16}$	·178	·447	·805	1·252	1·790	2·428	3·132	3·937
$\frac{1}{4}$	·226	·537	·940	1·432	2·015	2·684	3·445	4·295
$\frac{5}{16}$	·269	·626	1·074	1·611	2·260	2·953	3·758	4·653
$\frac{3}{8}$	·311	·714	1·206	1·790	2·459	3·219	4·069	5·009
$\frac{7}{16}$	·357	·805	1·342	1·981	2·684	3·489	4·384	5·369
$\frac{1}{2}$	·403	·895	1·478	2·148	2·908	3·758	4·698	5·727
$\frac{9}{16}$	·447	·985	1·623	2·327	3·132	4·027	5·012	6·085
$\frac{5}{8}$	·492	1·076	1·745	2·506	3·356	4·295	5·324	6·445
$\frac{11}{16}$	·537	1·176	1·880	2·684	3·579	4·564	5·637	6·801
$\frac{3}{4}$	·584	1·253	2·013	2·863	3·803	4·832	5·953	7·179
$\frac{13}{16}$	·638	1·342	2·147	3·042	4·027	5·100	6·264	7·616
$\frac{7}{8}$	·669	1·430	2·280	3·219	4·248	5·369	6·595	7·922
$\frac{15}{16}$	·704	1·509	2·404	3·388	4·462	5·625	6·888	8·227
1	·761	1·611	2·550	3·579	4·700	5·926	7·253	8·590
$1\frac{1}{8}$	·850	1·790	2·819	3·939	5·165	6·493	7·830	9·308
$1\frac{1}{4}$	·940	1·969	3·089	4·315	5·643	6·980	8·458	10·022
$1\frac{3}{8}$	1·029	2·150	3·376	4·703	6·040	7·519	9·082	10·738
$1\frac{1}{2}$	1·121	2·347	3·674	5·011	6·489	8·053	9·709	11·454
$1\frac{5}{8}$	1·226	2·554	3·890	5·369	6·933	8·588	10·333	12·168
$1\frac{3}{4}$	1·327	2·664	4·143	5·706	7·362	9·107	10·942	12·865
$1\frac{7}{8}$	1·337	2·815	4·379	6·035	7·780	9·614	11·538	13·553
2	1·478	3·042	4·698	6·443	8·277	10·201	12·216	14·317
$2\frac{1}{4}$	1·655	3·400	5·235	7·159	9·174	11·276	13·467	15·749
$2\frac{1}{2}$	1·833	3·758	5·774	7·874	10·067	12·349	14·722	17·181
$2\frac{3}{4}$	2·015	4·116	6·309	8·590	10·964	13·422	15·973	18·812
3	2·192	4·474	6·847	9·306	11·856	14·696	17·225	20·044

Weight per foot run in lbs. $= 2{\cdot}8634\,(D^2 - D'^2)$, D and D′ being the external and internal diameter in inches.

LEAD PIPES.—THE WEIGHT OF A LINEAL FOOT.

Bore in inches.	Thickness of Metal in parts of an inch.					
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$
	lbs.	lbs.	lbs	lbs.	lbs.	lbs.
$\frac{3}{16}$	·243	·607	1·092	1·699	2·427	3·277
$\frac{1}{4}$	·303	·728	1·273	1·942	2·730	3·641
$\frac{5}{16}$	·364	·850	1·456	2·184	3·034	4·004
$\frac{3}{8}$	·425	·971	1·638	2·427	3·337	4·369
$\frac{7}{16}$	·485	1·092	1·820	2·670	3·640	4·733
$\frac{1}{2}$	·546	1·214	2·013	2·913	3·944	5·097
$\frac{9}{16}$	·607	1·335	2·184	3·155	4·248	5·460
$\frac{5}{8}$	·667	1·520	2·366	3·398	4·551	5·825
$\frac{11}{16}$	·728	1·578	2·548	3·641	4·853	6·189
$\frac{3}{4}$	·789	1·699	2·731	3·873	5·157	6·553
$\frac{13}{16}$	·851	1·820	2·913	4·126	5·461	6·917
$\frac{7}{8}$	·910	1·942	3·095	4·368	5·764	7·281
$\frac{15}{16}$	·971	2·063	3·276	4·611	6·067	7·646
1	1·032	2·184	3·457	4·854	6·371	8·009
$1\frac{1}{4}$	1·274	2·670	4·186	5·825	7·585	9·466
$1\frac{1}{2}$	1·517	3·155	4·915	6·796	8·796	10·923
$1\frac{3}{4}$	1·760	3·641	5·642	7·768	10·013	12·375
2	2·001	4·127	6·372	8·734	11·223	13·833
$2\frac{1}{4}$	2·245	4·607	7·096	9·707	12·436	15·290
$2\frac{1}{2}$	2·489	5·100	7·829	10·683	13·654	16·762
$2\frac{3}{4}$	2·729	5·583	8·554	11·650	14·869	18·204
3	2·971	6·066	9·286	12·621	16·080	19·660

Weight per foot run $= 3 \cdot 8834\ (D^2 - D'^2)$, D and D′ being the external and internal diameter in inches.

Lead Water-pipes.—Weight per Lineal Yard.

Internal Diameter or Bore.	Safe Head of Water.	Weight.	Internal Diameter or Bore.	Reg. for Water Supply to the Metropolis. Branches. Weight.	Reg. for Water Supply to the Metropolis. Warning Pipes, &c. Weight.
inches.	feet.	lbs.	inches.	lbs.	lbs.
⅜	280	3·0	⅜	5	—
½	240	4·0	½	6	3
⅝	190	4·5	⅝	7½	—
¾	180	5·75	¾	9	5
1	160	8·5	1	12	7
1¼	150	13·0	1¼	16	—
1½	140	18·0	1½	9	{Supply Pipes for Water Closets.
1¾	120	20·0			
2	110	24·0			

Cast-iron Balls.—The Weight of Each.

Diameter in inches.	Weight in pounds.	Diameter in inches.	Weight in pounds.	Diameter in inches	Weight in pounds.
½	·017	3½	5·84	6½	37·44
¾	·058	3¾	7·19	7	46·76
1	·136	4	8·73	7½	57·52
1¼	·266	4¼	10·47	8	69·81
1½	·461	4½	12·42	8½	83·73
1¾	·731	4¾	14·62	9	99·40
2	1·09	5	17·04	9½	116·90
2¼	1·55	5¼	19·73	10	136·35
2½	2·13	5½	22·68	10½	157·84
2¾	2·25	5¾	25·93	11	181·48
3	3·68	6	29·45	11½	207·37
3¼	4·68	6¼	33·29	12	235·65

Tin Plates.—The Weight of a Box.

Brand Mark.	Number of Sheets per Box.	Size.	Weight.
		in. in.	lbs.
Singles—			
IC	225	13¾ × 10	112
IX	,,	,,	140
IXX	,,	,,	161
IXXX	,,	,,	182
IXXXX	,,	,,	203
IXXXXX	,,	,,	224
IXXXXXX	,,	,,	245
Small Doubles—			
SDC	200	15 × 11	167
SDX	,,	,,	188
SDXX	,,	,,	209
SDXXX	,,	,,	230
SDXXXX	,,	,,	251
SDXXXXX	,,	,,	272
SDXXXXXX	,,	,,	293
Large Doubles—			
DC	100	16¾ × 12½	98
DX	,,	,,	126
DXX	,,	,,	147
DXXX	,,	,,	168
DXXXX	,,	,,	189
DXXXXX	,,	,,	210
DXXXXXX	,,	,,	231
Taggers—			
TTT	450	14 × 10	112
Taggers	,,	,,	168
Extra Taggers	,,	14½ × 10½	196
SD Taggers	,,	15 × 11	203
Taggers	,,	13½ × 10½	182
Ditto	,,	13 × 10	168
Large Taggers	,,	15½ × 11½	217
Ternes—			
IC	112	14 × 20	112
IX	,,	,,	140

Hemp Ropes.—The Weight per Fathom (6 feet).

Shroud Laid. Tarred.		Hawser Laid. 3-Strand, White.		Hawser Laid. 3-Strand, Tarred.		Cable Laid.	
Circum. in inches.	Weight per fathom.	Circum. in inches.	Weight per fathom.	Circum. in inches.	Weight per Fathom.	Circum. in inches.	Weight per Fathom.
	lbs.		lbs.		lbs.		lbs.
1¼	·56	3	1·89	1½	·52	3	1·88
1¾	·76	3¼	2·22	1¾	·71	3¼	2·21
2	·99	3½	2·57	2	·92	3½	2·56
2¼	1·25	3¾	2·95	2¼	1·17	3¾	2·94
2½	1·54	4	3·32	2½	1·44	4	3·34
2¾	1·86	4¼	3·79	2¾	1·74	4½	4·23
3	2·22	4½	4·25	3	2·07	5	5·23
3¼	2·60	5	5·25	3¼	2·43	5½	6·32
3½	3·01	5½	6·35	3½	2·82	6	7·52
3¾	3·46	6	7·56	3¾	3·23	6½	8·83
4	3·94	6½	8·87	4	3·68	7	10·24
4¼	4·44	7	10·29	4¼	4·15	7½	11·76
4½	4·98	7½	11·81	4½	4·66	8	13·38
4¾	5·55	8	13·44	4¾	5·19	8½	15·21
5	6·25	8½	15·17	5	5·75	9	16·93
5¼	6·78	9	17·01	5¼	6·34	9½	18·86
5½	7·44	9½	18·95	5½	6·96	10	20·90
6	8·86	10	21·00	6	8·28	10½	23·04
				6½	9·72	11	25·29
				7	11·27	11½	27·64
				7½	12·94	12	30·10
				8	14·72	12½	32·65
				8½	16·62	13	35·32
				9	18·63	13½	38·09
				9½	20·76	14	40·96
				10	23·00	15	47·03
				10½	25·36	16	53·51
				11	27·83	17	60·40
				12	33·12	18	67·72

Rule to find the Weight:—

C = Circumference in inches.
W = Weight in lbs. per fathom.
A = ·246 for Shroud laid rope.
= ·230 Hawser, tarred.
= ·210 Ditto, white.
= ·209 Cables.

Then

$$W = A \times C^2.$$

Note.—For the weight of Manilla hemp ropes deduct $\frac{1}{6}$th from the above, and for coir ropes deduct $\frac{1}{3}$rd.

ROUND AND FLAT IRON WIRE ROPES.
THE WEIGHT OF A FATHOM (6 FEET).

Round.				Flat.	
Circum. in inches.	Weight per Fathom.	Circum. in inches.	Weight per Fathom.	Size in inches.	Weight per Fathom.
	lbs.		lbs.		lbs.
1	1·0	3½	10·75	1⅞ × ½	8·0
1½	1·75	3⅝	11·5	2⅛ × ½	10·0
1⅝	2·0	3¾	12·6	2¼ × ½	11·0
1¾	2·5	3⅞	13·5	2½ × ½	12·0
1⅞	3·0	4	14·5	2¾ × ½	13·3
2	3·5	4¼	15·5	2¾ × ⅝	15·0
2⅛	3·9	4⅜	16·5	3 × ⅝	16·5
2¼	4·25	4½	17·6	3¼ × ⅝	18·0
2⅜	4·8	4⅝	18·6	3½ × ⅝	20·0
2½	5·5	4¾	20·0	3¾ × ¾	22·0
2⅝	6·0	5	21·5	4 × ¾	24·0
2¾	6·5	5½	26·0	4¼ × ¾	26·0
2⅞	7·0	6	31·5	4½ × ¾	28·4
3	7·6	6½	36·75	4⅝ × ¾	32·0
3⅛	8·2	7	42·5	4⅝ × ⅞	34·0
3¼	8·8	7½	46·75	—	—
3⅜	9·5	8	51·75	—	—

NOTE.—The weight of steel wire ropes may be taken as equal to that of iron wire ropes.

Wire.—The Weight of 100 Lineal Feet.
Standard Gauge.

S. W. Gauge.	Diameter in Decimals of an inch.	Iron.	Steel.	Brass.	Copper.
		lbs.	lbs.	lbs.	lbs.
0	·324	27·769	28·055	30·575	31·777
1	·300	23·807	24·053	26·213	27·244
2	·276	20·151	20·358	22·186	23·059
3	·252	16·799	16·972	18·496	19·223
4	·232	14·238	14·385	15·676	16·293
5	·212	11·889	12·011	13·090	13·605
6	·192	9·752	9·852	10·737	11·159
7	·176	8·194	8·278	9·022	9·377
8	·160	6·772	6·842	7·456	7·749
9	·144	5·485	5·542	6·039	6·277
10	·128	4·334	4·379	4·772	4·960
11	·116	3·559	3·596	3·917	4·073
12	·104	2·861	2·891	3·150	3·274
13	·092	2·239	2·262	2·465	2·562
14	·080	1·693	1·710	1·864	1·937
15	·072	1·371	1·385	1·510	1·569
16	·064	1·084	1·095	1·193	1·240
17	·056	·8296	·8381	·9134	·9493
18	·048	·6095	·6158	·6710	·6974
19	·040	·4232	·4276	·4660	·4843
20	·036	·3428	·3464	·3775	·3923
21	·032	·2709	·2737	·2982	·3100
22	·028	·2074	·2095	·2283	·2373
23	·024	·1524	·1539	·1678	·1744
24	·022	·1280	·1294	·1410	·1465
25	·020	·1058	·1069	·1165	·1211
26	·018	·0857	·0866	·0944	·0981
27	·0164	·0715	·0719	·0783	·0814
28	·0148	·0579	·0585	·0638	·0660
29	·0136	·0489	·0494	·0539	·0560
30	·0124	·0407	·0411	·0448	·0464
31	·0116	·0356	·0360	·0392	·0406
32	·0108	·0309	·0312	·0340	·0353
33	·0100	·0265	·0267	·0291	·0303
34	·0092	·0224	·0226	·0247	·0256
35	·0084	·0187	·0189	·0206	·0214
36	·0076	·0152	·0154	·0168	·0175

SLATES.—THE WEIGHT OF A SUPERFICIAL FOOT.

Description.	Thickness in inches.															
	⅛	¼	⅜	½	⅝	¾	⅞	1	1¼	1½	1¾	2	2¼	2½	2¾	3
	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Welsh	1·88	3·75	5·63	7·50	9·38	11·25	13·13	15·00	18·75	22·50	26·25	30·00	33·75	37·50	41·25	45·00
Westmoreland	1·82	3·65	5·47	7·29	9·11	10·94	12·76	14·58	18·23	21·88	25·52	29·17	32·81	36·46	40·10	43·75
Cornish.. ..	1·67	3·33	5·00	6·67	8·33	10·00	11·67	13·33	16·67	20·00	23·33	26·67	30·00	33·33	36·67	40·00

THE NUMBER OF SUPERFICIAL FEET IN A TON.

Description.	Thickness in inches.															
	⅛	¼	⅜	½	⅝	¾	⅞	1	1¼	1½	1¾	2	2¼	2½	2¾	3
Welsh	1195	597	398	299	239	199	171	149	119	100	85	75	66	60	54	50
Westmoreland	1229	614	410	307	246	205	177	154	123	102	88	77	68	61	56	51
Cornish.. ..	1344	672	448	336	269	224	192	168	134	112	96	84	75	67	61	56

SLATES.—WEIGHT PER THOUSAND (1200).

Description.	Size.	Penrhyn or Bangor.		Port Madoc.	
		1st Quality.	2nd Quality.	1st Quality.	2nd Quality.
	in. in.	cwt.	cwt.	cwt.	cwt.
Princesses ..	24 × 14	75	84	65·5	76
Duchesses ..	24 × 12	59	80	57	66·5
Marchionesses	22 × 12	54	69	52·5	62
Countesses ..	20 × 10	39	52	38	47·5
Viscountesses	18 × 10	35	46	33	43
Ditto	18 × 9	33	43	28·5	38
Ladies, Wide..	16 × 10	30	41	28·5	36
Ditto, Large ..	16 × 8	24	32	22·5	27·5
Ditto	15 × 8	25	33	—	—
Ditto	14 × 12	31·5	42	31	38
Ditto, Small ..	14 × 8	21	25	21	23·5
Plantations ..	13 × 10	23·5	29·5	25	—
Doubles	13 × 6	15	19	—	—
Ditto	12 × 8	17½	21	—	—

CORRUGATED IRON ROOFING.

S. W. Gauge.	Size of Sheets.	Weight per Square as laid.	No. of sup. feet per ton before laying.
	ft. ft. ft. ft.	lbs.	
16	6 × 2 to 8 × 3	363	746
18	6 × 2 „ 8 × 3	274	957
20	6 × 2 „ 8 × 3	203	1355
22	6 × 2 „ 7 × 2½	162	1538
24	6 × 2 „ 7 × 2½	140	1866
26	6 × 2 „ 7 × 2½	112	2354

3 lbs. of rivets are required for each square (100 sup. feet) of roofing.

If the sheets are galvanised add $\frac{1}{100}$th part to the weight in the table.

Stone.—The Quantity equal to a Ton in Weight.

	Cubic feet.		Sup. feet.
Vein marble	13	2 in. York paving ..	86
Statuary ditto	13½	2½ „ ditto ..	70
Granite	13½	3 „ ditto ..	57½
Kentish rag	13½	4 „ York landing ..	43
Purbeck	13¾	6 „ ditto ..	28¼
Yorkshire	14½	8 „ ditto ..	21¼
Blue Lias limestone ..	14½	2 „ Purbeck paving ..	83
Portland (best bed) ..	15	2½ „ ditto ..	66¼
„ (top bed) ..	16½	3 „ ditto ..	55¼
„ (roach) ..	17½	3 „ Granite	54
Cragleith	15½	4 „ ditto	39
Bath	18	6 „ ditto	27
Caen	18	9 „ ditto	18

The Weight of Limes and Cements.

Measured in large quantities.

Description.	Weight per bushel.	Weight per cubic foot.
In Lump (from Kiln)	lbs.	lbs.
Plymouth stone lime	70	54·5
Grey Chalk ditto	56	44·0
Keynsham blue Lias	80	62·4
Lyme Regis ditto	75	58·5
Ground (Fresh)		
Plaster of Paris	74	57·7
Keynsham blue Lias	68	53
Lyme Regis ditto	70	54·5
Roman cement	80	62·4
Portland cement	110	85·7

Paving &c.—Weight per Foot Super.

Thickness in inches.	Yorkshire. lbs.	Purbeck. lbs.	Thickness in inches.	Marble Slabs. lbs.
2	26	27	½	7·17
2½	32·5	33·75	¾	10·75
3	39	40·5	1	14·33
3½	45·5	47·25	1¼	17·92
4	52	54	1½	21·5
4½	58·5	60·75	1¾	25·08
5	65	67·5	2	28·67
6	78	81	2½	35·83

Bricks and Tiles.—Weight per Thousand.

Description.	Size.	Weight of each.	Weight per 1000.
Bricks.	in. in. in.	lbs.	cwt.
London stocks ..	8¾ × 4¼ × 2¾	6·81	60¾
Red kiln	,,	7·00	63
Welsh fire	9 × 4½ × 2¾	7·84	65
Paving	9 × 4½ × 1¾	5·00	45
Dutch clinkers ..	6¼ × 3 × 1½	1·55	14
Roofing Tiles.			
Plain	10½ × 6 × ½	1·90	17
Ditto	11 × 6½ × ⅝	2·69	24
Pan	13½ × 9½ × ½	5·25	47
Paving Tiles.			
Squares	6 × 6 × 1	2·16	19¼
Ditto	9¾ × 9¾ × 1	5·70	50
Ditto	11¾ × 11¾ × 1½	12·42	111
Hexagons	6 × 6 × ⅞	1·63	14½
Ditto	6 × 6 × 1	1·86	16½

The Weight of Ridge Tiles.

Description.	Length. ft.	Length. in.	Breadth of Wings. ft.	Breadth of Wings. in.	Weight per hundred. cwt.	Weight per hundred. qrs.
Plain	1	6	0	6	10	0
Ditto	1	6	0	7	14	0
Rolled top	1	6	0	6	12	2
Ditto	1	6	0	7	18	0
Rolled capped	1	6	0	7	18	0
Capped	1	6	0	6	12	0
Ditto	1	6	0	7	15	0
Ditto, angular	1	6	0	7	17	0
Ditto, short	1	0	0	7	10	0
Pyramid	1	6	0	7	20	0

The Weight of Men and Animals.

Average weight of a man	=	150	lbs.
A crowd of men packed on a weigh-bridge, per foot super	=	84	„
Ditto, closely packed	=	120	„
Horse, cavalry, heavy	=	11	cwt.
Ditto, light, for riding	=	8	„
Ditto, strong, for carting	=	14	„
Elephant, average	=	60	„
Camel „	=	10¼	„
Ox, small „	=	6	„
Ditto, large „	=	10	„
Cow „	=	6½	„
Heifer „	=	3¼	„
Pig, small „	=	1	„
Ditto, large „	=	1¾	„
Sheep, small „	=	65	lbs.
Ditto, large „	=	90	„

THE WEIGHT OF SEEDS AND FORAGE.

	lbs. per bushel.	lbs. per cub. foot
Barley (new)	50	39
Beans	66	51·4
Clover, Red	62	48·3
Ditto, White	68	53
Flax Seed	53	41·3
Flour	54	42·1
Grass Seed, meadow mixed	15	11·7
Ditto, Rye	16	12·5
Hemp Seeds	43	33·6
Oats (new)	40	31·2
Peas	63	49·1
Rape Seed	48	37·4
Rye	54	42·1
Turnip Seed, Swedish	50	39
Wheat (new)	60	47·8
Ditto (kiln dried)	58	45·2
Hay in bundles, loose	—	5
Ditto in trusses, well pressed	—	8
Straw, Wheat	—	4·3
Ditto, Oat	—	4

EARTH, &c.—THE QUANTITY WHICH EQUALS A TON IN WEIGHT (average).

	cub. ft.		cub. ft.
Mud, just dredged	18	Sand, pit, as excavated	21
Chalk, solid	18	Earth, semi-fluid	22
Marl	19	Thames ballast	22
Clay, stiff	19	Shingle, clean	23
Gravel, unscreened	19	Chalk in lumps	29
Sand, river	20	Nightsoil	31
Chalk, dried in an oven	20	Earth, vegetable	32

WATER.—BAROMETER AT 30 INCHES.

1 cubic inch at 62° Fahr.	=	·0361 lbs
1 gallon ,,	=	10·0000 ,,
1 cubic foot ,,	=	62·3550 ,,
,	=	6·2355 gallons.
35·923 cubic feet ,,	=	1 ton.

WATER—*continued.*

1 cubic foot at 39°·1 Fahr. (max. density) = 62·425 lbs.
Head of water (at 62°) on the square inch, equivalent to 1 lb. pressure .. .. } = 2·309 feet.
1 cub. ft. of water (at 62°) = 815·7 cub. ft. of dry air (at 62°).
Ditto, ditto (at 39°·1) = 773 cub. ft. of dry air (at 39°·1).
1 cub. in. of water (at 62°) = 1812 cub. in. of ordinary coal gas.
The weight of pure water is to that of sea water as 1 is to 1·026.

THE WEIGHT OF COAL.—AS USED IN COMMERCE (per cubic foot).

Welsh anthracite	= 58·25 lbs.
„ bituminous	= 53·00 „
Lancashire	= 50·00 „
Newcastle	= 50·00 „
Scotch	= 53·00 „

Space occupied by a ton.

Welsh anthracite	= 39 cub. ft.
„ bituminous	= 43 „
Lancashire	= 44 „
Newcastle	= 45 „
Scotch	= 43 „

The Navy allowance for stowage = 48 cub. ft.

THE WEIGHTS OF VARIOUS SUBSTANCES.

METALS (per cubic foot).

	lbs.		lbs.
Aluminium	162	Lead, cast	710
Antimony, cast	419	Mercury, fluid	848
Bismuth, cast	614	„ solid	977
Brass, cast	525	Nickel, cast	788
„ wire	534	Platinum, pure	1220
Bronze	513	„ wire drawn	1300
Copper, cast	550	„ hammered	1280
„ sheet and wire	555	Pewter	453
Gold, pure	1210	Silver, pure	655
„ standard	1108	„ standard	658
Gun metal	549	Steel	490
Iron, wrought	485	Tin, cast	456
„ cast	450	Type-metal	653
Lead, milled	712	Zinc	450

THE WEIGHTS OF VARIOUS SUBSTANCES—*continued.*

STONES, EARTHS, &c.

	Weight per cub. ft. in lbs.
Asphalte, fine, without grit	137
Ditto, coarse, with grit	130
Basalt	182
Bath stone (Box)	123
Beeswax, coarse	58
Ditto, clarified	62
Bitumen	62
Books	40
Bramley Fall stone	150
Brick, common London stock	115
Ditto, red-facing	130
Ditto, fire	150
Brickwork, in mortar	112
Ditto, in Portland cement	115
Caen stone	125
Cement, Portland	86
Ditto, Portland and sand equal parts	130
Ditto, Roman	62
Ditto, Roman and sand, equal parts	112
Chalk, solid	125
Ditto, dry	112
Ditto, in lumps as excavated	75
Charcoal, from birch	34
Ditto, from fir	28
Ditto, from oak	21
Ditto, from pine	18
Clay, potters'	120
Ditto, with gravel	130
Ditto, ordinary	120
Coal, solid	80
Coke, ditto	60
Concrete, Portland cement (1 to 6)	130
Concrete, Portland cement (1 to 8)	126
Ditto common lime	125
Emery	250
Earth, vegetable	70
Ditto, loamy	80
Ditto, semi-fluid	100
Flint	162
Freestone, hewn	140
Glass, white flint	188
Ditto, plate	184
Ditto, crown	158
Gravel, Thames	100
Ditto, coarse, mixed with sand	110
Granite, Aberdeen grey	167
Ditto, ditto, red	165
Ditto, Cornish	166
Ditto, Guernsey	185
Gunpowder, large grain	57
Ditto, fine grain	56
Guttapercha	61
Gypsum, natural state	140
Hair, ox, dried	11
Ice (32° Fahr.)	58
Ivory	114
Indiarubber	62
Kentish rag stone	166
Limestone, Lias	156
Ditto, magnesian (Bolsover)	151
Ditto, ditto (Roche Abbey)	139
Ditto, Plymouth	167
Ditto, compact (mountain)	170
Lime, ordinary stone in lump	55

THE WEIGHTS OF VARIOUS SUBSTANCES—*continued.*

STONES, EARTHS, &c.

	Weight per cub. ft. in lbs.
Lime, grey chalk in lump	44
Marble, average	170
Marl	120
Masonry, rubble ..	140
Ditto, flint	148
Ditto, ashlar, Portland	140
Ditto, ditto Purbeck	150
Ditto, ditto granite	160
Mortar, Lime, old ..	90
Ditto, new	110
Ditto, well tempered ..	115
Millstone Grit	145
Mud (just dredged) ..	124
Peat, Irish, hard and dry	55
Pitch	72
Plaster of Paris, cast..	80
Portland stone (best bed)	145
Ditto, (top bed)	136
Ditto (roach)	127
Porphyry, green.. ..	180
Ditto, red	175
Pumice stone	57
Purbeck stone	162
Puzzolana	170
Quartz	166

	Weight per cub. ft. in lbs.
Rottenstone	124
Salt	43
Ditto, rock, broken ..	50
Sand, river	118
Ditto, Thames	103
Ditto, pit, clean, coarse	100
Ditto, pit, fine and clean	95
Sandstone, Craigleith..	145
Shingle	95
Slate, Welsh	181
Ditto, ditto rag	172
Ditto, Anglesey	180
Ditto, Westmoreland, pale blue	175
Ditto, ditto, dark blue	174
Ditto, ditto, greenish	173
Ditto, Cornish, grey blue	160
Snow, fresh fallen	5 to 12
Sulphur, melted	124
Ditto, native	127
Syenite, Mount Sorrel	164
Tallow	59
Tar, coal	63
Tiles, average	115
Whinstone, Scotch ..	172
Yorkshire, paving ..	156

The Weight of Various Substances—*continued.*

Timber (dry).

Common Name.	Botanical Name.	Weight per cubic ft. in lbs.
Pine Wood (Nat. Order, Coniferæ):—		
Cedar, West Indian ..	*Cedrela odorata* ..	30
" Virginian Red ..	*Juniperus Virginiana*	35
" Bermuda	*J. Bermudiana*	28
" of Lebanon ..	*Cedrus Libani*	30
Fir, Norway Spruce ..	*Abies excelsa*	30
" Hemlock	*A. Canadensis*	31
Larch	*Larix Europæa* ..	35
Pine, Northern, Memel	*Pinus Sylvestris* ..	36
" " Riga ..	"	34
" Red, America ..	*P. rubra*	36
" Pitch " ..	*P. Australis*	41
" White " ..	*P. strobus*	28
" Kauri, N. Zealand	*Dammara Australis* ..	38
Yellow Wood, S. Africa	*Taxus elongatus* ..	40
Yew	" *baccata*	50
Hard Wood (Nat. Order, Various):—		
Acacia	*Robinia pseudo-acacia*	50
Alder	*Alnus glutinosa* ..	35
Apple-tree	*Pyrus malus*	49
Ash	*Fraxinus excelsior* ..	50
Bay-tree..	*Laurus nobilis*.. ..	51
Beech	*Fagus Sylvatica* ..	51
Birch	*Betula alba*	45
Blue Gum	*Eucalyptus globulus*	53
Box (hard Dutch) ..	*Buxus sempervirens*	80
Cherry-tree	*Prunus cerasus* ..	42
Chestnut, Sweet	*Castanea vesca*	38
" Horse	*Æsculus hippocastanum*	40
Cork (bark)	*Quercus suber*	15
Crab-tree	*Pyrus malus*	47
Cypress	*Cupressus sempervirens*	40

THE WEIGHTS OF VARIOUS SUBSTANCES—*continued.*

Common Name.	Botanical Name.	Weight per cubic ft. in lbs.
Hard Wood—continued.		
Ebony, West Indian	*Brya ebenus*	70
„ American.. ..	— —	80
Elder	*Sambucus nigra* ..	43
Elm..	*Ulmus campestris* ..	39
Greenheart	*Nectandra rodiæi* ..	60
Hazel	*Corylus avelana* ..	38
Hornbeam	*Carpinus betulus* ..	53
Iron Bark	*Eucalyptus resinifera*	64
Ironwood, Black	*Olea laurifolia*.. ..	65
Jarrah	*Eucalyptus marginata*	51
Lignum Vitæ..	*Guaiacum officinale*..	80
Locust, Jamaica	*Hymenæa courbaril*..	42
Mahogany, St. Domingo	*Swietenia mahogoni*	53
„ Honduras ..	„ „	42
Maple	*Acer campestris* ..	47
Mora	*Mora excelsa*	57
Oak, English..	*Quercus pedunculata*	50
„ Dantzic..	„ „	48
„ American White..	*Q. alba*	53
„ „ Red ..	*Q. rubra*	47
„ „ Live ..	*Q. virens*	70
Pear-tree	*Pyrus communis* ..	42
Plum-tree	*Prunus domestica* ..	45
Poon	*Calophyllum Burmanni*	40
Poplar, White Spanish	*Populus alba*	33
„ Black	*P. nigra*	28
„ Lombardy ..	*P. fastigiata*	26
Sâl	*Shorea robusta*	62
Sissoo	*Dalbergia sissoo* ..	56
Stringy Bark..	*Eucalyptus gigantea*	54
Sneezewood	*Pteroxylon utile* ..	68
Sycamore	*Acer-pseudo-platanus*	37
Teak	*Tectona grandis* ..	46
Walnut	*Juglans regia*	44
„ White (Hickory)	*J. alba*	58
„ Black	*J. nigra*	60
Willow	*Salix alba*	34

THE WEIGHTS OF VARIOUS SUBSTANCES—*continued.*

LIQUIDS.

—	Weight of Water = 1000.	Weight per gallon in lbs.
Acid, sulphuric..	1850	18·5
„ nitric	1271	12·7
„ muriatic	1200	12·0
Alcohol of commerce	825	8·2
„ proof spirit	916	9·2
Oil, linseed..	940	9·4
„ whale	923	9·2
„ of turpentine	870	8·7
Mercury at 32° Fahr.	13596	136·0
Milk	1030	10·3
Naphtha, coal	848	8·5
„ wood..	798	8·0
Petroleum	878	8·8
Tar	1015	10·1
Water from Mediterranean	1028	10·3
„ „ Irish Channel	1026	10·3
„ „ ice..	1001	10·0
„ distilled, 62° Fahr.	1000	10·0
Vinegar	1009	10·1

NOTE.—To find the specific gravity. Divide the weight of the substance by that of distilled water at the same temperature = 62° Fahr. in the foregoing tables.

GASES.

Pressure = 1 Atmosphere (29·921 inches).

	Specific Gravity.
Air, dry at 39°·1 Fahr. = ·0807 lbs. per cubic foot ..	1·000
„ „ 62 „ ·0764 lbs. „ „ ..	·946
„ saturated with vapour at 62° Fahr. = ·0755 lbs. per cubic foot	·936
Ammoniacal Gas	·537
Carbonic acid (*carbon dioxide*)	1·529
„ oxide (*carbon monoxide*)	·967

The Weights of Various Substances—*continued.*

	Specific Gravity.
Chlorine	3·440
Cyanogen	1·806
Hydrogen = ·005592 lbs. per cubic foot	·069
" carburetted, or marsh gas	·559
Oxygen = ·089256 lb. per cubic foot	1·106
Steam at 212° = ·03797 lb. per cubic foot	·471
Sulphuretted hydrogen	1·191
Coal gas, 40° Fahr. = ·0363 lb. per cubic foot	·450
" common = ·0418 lb.	·518
" cannel, 40° Fahr.	·550

To Find the Weight of Castings from that of their Patterns.

Multiply weight of white pine pattern by 17 for cast iron.
Ditto " " " 18 " brass.
Ditto " " " 19 " copper.
Ditto " " " 25 " lead.

MEMORANDA CONNECTED WITH SANITARY ENGINEERING.

AIR.

Composition of atmospheric air in its natural state:

	Oxygen	20·86
	Nitrogen	78·00
	Carbon dioxide	·04
	Aqueous vapour, according to temperature	1 to 12 grains.
	Ammonia	a trace.
	Ozone (a form of oxygen)	variable.
	Organic matter	variable.
	Salts of sodium	variable.
	Inorganic matter	variable.
In towns ..	Hydrogen sulphide	a trace.

Air is considered impure when mixed with other gases, or holding in suspension organic and inorganic substances injurious to health.

The GASEOUS impurities are chiefly:

Carbon dioxide in excess.

Carbon monoxide, 5 per cent. of which in air has produced poisonous symptoms in man, and 1 per cent. has proved rapidly fatal to animals.

Carburetted hydrogen (coal gas) produces poisonous symptoms when present to the extent of 20 to 30 per cent.

Hydrogen sulphide affects dogs and horses when present to the extent of about ·13 to ·4 per cent., although a man can inhale for a short time an atmosphere containing nearly 3 per cent.

In addition to these are nitrous acid and other compounds of nitrogen; also vapours from decaying organic matter.

The SUSPENDED matter is chiefly dust, seeds of plants, spores of fungi and bacteria, germs and débris of organic matter. According to the experiments of Miguel, Carnelly, Haldane and others, only 12 to 28 bacteria per cubic foot are ordinarily found in the air of open situations; they are much more numerous in the air of towns, and still more so in badly ventilated rooms.

It is considered by hygienists that the quantity of carbon dioxide is a convenient test of the purity of air as regards the ventilation of rooms which are rendered impure by exhalations from animals and the combustion of fuel, oil, gas, &c.

Carbon dioxide may produce fatal results in man when present to the extent of 5 to 10 per cent., and air which contains only ·09 to ·1 per cent. becomes perceptibly impure; a candle becomes extinguished when the carbon dioxide is $2\frac{1}{2}$ per cent., if the oxygen is at the same time reduced to $18\frac{1}{2}$ per cent., or with 4 per cent. if the oxygen is not materially diminished.

Dr. Parkes has suggested that air should be considered impure and unfit for respiration when it contains more than ·06 per cent. = ·0006 cubic foot, in every cubic foot of air.

Sources of carbon dioxide and other impurities in the air of rooms:

An adult man in repose inhales about 16 to 18 cubic feet of air per hour, and gives off in the same period from ·5 to ·7 cubic feet of carbon dioxide. These figures are much increased during exertion; if the work is severe they may be doubled.

An ordinary gas burner for every cubic foot of coal gas consumed per hour, will destroy the oxygen of about 8 cubic feet of air, and produces about 2 cubic feet of carbon dioxide, also from $\frac{1}{2}$ to $1\frac{1}{2}$ cubic feet of watery vapour, with about $\frac{1}{2}$ a grain of sulphuric acid. It will also raise the temperature of the air in the room by several degrees.

An oil lamp burning 154 grains of oil per hour consumes the oxygen of $3\frac{1}{4}$ cubic feet of air, and produces about $\frac{1}{2}$ a cubic foot of carbon dioxide, or 23 cubic feet per lb. of oil. A lb. of oil requires at least 150 cubic feet of air for complete combustion.

A good sperm or paraffin candle produces about $\frac{3}{10}$th of a cubic foot of carbon dioxide per hour. When the illuminating power is equal, candles give more impurity to the air than gas, but less water.

The deterioration of the air from these causes

being unavoidable, fresh air should be introduced in sufficient quantity to dilute the impurities until they cease to be injurious to health.

To ascertain the quantity of air that must be supplied to effect the above purpose we have the following formula by Dr. Parkes.

Let e = The quantity of carbon dioxide exhaled by an adult per hour (= ·6 cubic feet in repose).

r = The quantity of carbon dioxide per cubic foot *permissible* in wholesome air (·0006 according to Parkes, Chaumont and others).

R = The quantity of carbon dioxide per cubic foot in the air naturally (say ·0004).

Q = The volume of air in cubic feet to be supplied per hour.

Then
$$Q = \frac{e}{r - R}.$$

This formula gives the following values of Q according to the value of r.

When r = ·0006	(Parkes' standard)	Q = 3000
= ·0007	„ „	= 2000
= ·0008	„ „	= 1500
= ·0009	„ „	= 1200
= ·0010	„ „	= 1000

NOTE.—The air may be changed less frequently in sitiing rooms which are only partially occupied during the day than in dormitories, schools and workrooms.

According to Dr. J. Lane Notter, Professor of Hygiene at the Army Medical School, Netley, the amount of air required hourly in cubic feet is—

	In repose.	In gentle exertion.	In hard work.
Adult males	3000	4500	9000
„ females	2000	3000	6000
Children..	1500	2250	4500

An ordinary GAS BURNER consuming 5 cubic feet of gas per hour requires 9000 cubic feet of air, or as much as 3 men.

An OIL LAMP requires as much as 1 man.

A CANDLE requires about half as much as a man.

According to Dr. Angus Smith, a greater quantity

of carbon dioxide is admissable when the air is cold than when it is warm.

The quantity of moisture in wholesome air should not be less than 40 per cent. of saturation.

To ascertain the quantity of moisture in the air.

Multiply the difference between the wet and dry bulbs of the hygrometer by the factor in the table No. 1, and the product subtracted from the temperature of the *dry* bulb will be temperature of the dew point by which the weight of vapour in the air may be obtained from table No. 2.

Table No. I., for Computing the Dew Point, (Fahr.) (Glaisher's Factors.)

Dry Bulb Thermometer.	Factor.	Dry Bulb Thermometer.	Factor.	Dry Bulb Thermometer.	Factor.
°		°		°	
20	8·14	41	2·26	62	1·86
21	7·88	42	2·23	63	1·85
22	7·60	43	2·20	64	1·83
23	7·28	44	2·18	66	1·81
24	6·92	45	2·16	68	1·79
25	6·53	46	2·14	70	1·77
26	6·08	47	2·12	72	1·75
27	5·61	48	2·10	74	1·73
28	5·12	49	2·08	76	1·71
29	4·63	50	2·06	78	1·69
30	4·15	51	2·04	80	1·68
31	3·70	52	2·02	82	1·67
32	3·32	53	2·00	84	1·66
33	3·01	54	1·98	86	1·65
34	2·77	55	1·96	88	1·64
35	2·60	56	1·94	90	1·63
36	2·50	57	1·92	92	1·62
37	2·42	58	1·90	94	1·60
38	2·36	59	1·89	96	1·59
39	2·32	60	1·88	98	1·58
40	2·29	61	1·87	100	1·57

TABLE No. 2.—WEIGHT IN GRAINS OF A CUBIC FOOT OF VAPOUR (BAR. 30 IN.) AT THE TEMPERATURE OF THE DEW POINT, viz. *the weight of vapour that can be sustained at that temperature without being visible.*

Temp. of Dew point, Fahr.	Weight.	Temp. of Dew point, Fahr.	Weight.	Temp. of Dew point, Fahr.	Weight.	Temp. of Dew point, Fahr.	Weight.
°	grs.	°	grs.	°	grs.	°	grs.
1	·57	30	1·97	54	4·71	78	10·31
5	·68	32	2·13	56	5·04	80	10·98
10	·84	34	2·30	58	5·39	82	11·67
12	·92	36	2·48	60	5·77	84	12·40
14	1·00	38	2·66	62	6·17	86	13·17
16	1·09	40	2·86	64	6·59	88	13·98
18	1·19	42	3·08	66	7·04	90	14·85
20	1·30	44	3·32	68	7·51	92	15·74
22	1·42	46	3·56	70	8·01	94	16·69
24	1·54	48	3·82	72	8·54	96	17·68
26	1·68	50	4·10	74	9·10	98	18·73
28	1·82	52	4·39	76	9·69	100	19·84

A cubic foot of Dry Air at 32° Fahr. weighs 566·85 grains, at 60° Fahr. 536·28 grains, and at 100° Fahr. 497·93 grains. The barometer being at 30 inches.

APJOHN'S FORMULA FOR DEW POINT.

If temperature be above 32°

$$F = f - \frac{d}{87} \times \frac{h - f}{30}.$$

If below 32°

$$F = f - \frac{d}{96} \times \frac{h - f}{30}.$$

f = Elastic force at temperature of wet bulb thermometer, obtained from the following Table.

d = Difference of the two thermometers.

h = Observed height of barometer.

F = Elastic force at the dew point temperature, or its value in the following Table.

TABLE OF ELASTIC FORCE OR TENSION OF AQUEOUS VAPOUR IN INCHES OF MERCURY, according to Apjohn.

Temp. Fahr.	Force. F.	Temp. Fahr.	Force. F.	Temp. Fahr.	Force. F.	Temp. Fahr.	Force. F.
°	ins.	°	ins.	°	ins.	°	ins.
30	·165	51	·374	72	·784	92	1·501
31	·173	52	·388	73	·811	93	1·548
32	·181	53	·403	74	·839	94	1·597
33	·188	54	·418	75	·868	95	1·647
34	·196	55	·433	76	·897	96	1·698
35	·204	56	·449	77	·927	97	1·751
36	·212	57	·466	78	·958	98	1·805
37	·220	58	·482	79	·990	99	1·861
38	·229	59	·500	80	1·023	100	1·918
39	·238	60	·518	81	1·057	101	1·976
40	·248	61	·537	82	1·092	102	2·037
41	·257	62	·556	83	1·128	103	2·098
42	·267	63	·576	84	1·165	104	2·162
43	·278	64	·596	85	1·203	105	2·227
44	·288	65	·617	86	1·242	106	2·293
45	·299	66	·639	87	1·282	107	2·361
46	·311	67	·662	88	1·324	108	2·431
47	·323	68	·685	89	1·366	109	2·503
48	·335	69	·709	90	1·410	110	2·557
49	·348	70	·733	91	1·455	212	29·92
50	·361	71	·758				

To find the Amount of Evaporation from Water in Open Vessels or Reservoirs. (Box.)

$$E = (243 + 3\cdot 7\ t) \times (F - v).$$

E = Evaporation per square foot per hour in grains.
t = Temperature of the water.
F = Elastic force of vapour at temperature t, from the Table.
v = Elastic force of vapour actually present in the air as obtained by the hygrometer.

Ventilation.

To replace an impure by a pure atmosphere is the object of ventilation.

This in a dwelling room should be effected without causing draughts, which according to Dr. Parkes are often more deadly than the foul air.

The velocity at which air can be moved in ventilating a room without endangering the health of the occupants, is from $2\frac{1}{2}$ to $3\frac{1}{2}$ feet per second, when the temperature is 55° to 70° Fahr.

Cubic space.—This will depend on the number of times the air can be removed in an hour without material inconvenience to the inmates. Dr. De Chaumont limits it to six times, which appears excessive. If the air in a room be changed *three* times in every hour, no sensible inconvenience will be felt from draughts, and taking the quantity to be supplied at 3000 cubic feet per head per hour, a space of 1000 cubic feet would be required for each individual in the room.

A large space has an advantage over a small one, as the air in it is not cooled so rapidly by the introduction of cold air from the outside.

Space allowed in public buildings:

English barracks..	per man	600	cub. feet.
" hospitals (military)	"	1200	"
" " " in the tropics	"	1500	"
" " (civil)	"	850 to 1200	"
" Poor Law Board dormitories	"	300	"

Net space to be allowed in all well-arranged buildings:

Living and day-rooms	per head	600	cub. feet.
Dormitories	"	1000	"
Hospitals	per patient	1300	"
" for acute and surgical cases	"	1500	"
Stables and cow houses ..	per horse or cow	1600	"
Infirmaries	" "	1900	"
Piggeries (closed)	per animal	700	"
Dog kennels "	"	95 to 200	"
Fowl houses "	"	4 to 6	"

Size of Inlets and Outlets.

An ordinary fireplace burning about 2 lbs. of coal per hour will carry off through the chimney about 29,000 cubic feet of heated air per hour. The height of the chimney being 50 feet, its area 1 square foot, and the difference between the mean temperature in the flue and that of the external air in the passages leading to the room, 40° Fahr.

NOTE.—The mean temperature in the chimney of the author's library at the time of writing these pages is 110°, that of the air in the room 3 feet from the floor and at the opposite side to the fireplace 55°, and the external air 33°. The height of the chimney being 40 feet, its area about 1 square foot, and the quantity of air passing into the flue nearly 33,000 cubic feet per hour.

The theoretical formula usually given to calculate the velocity of air in chimneys and air shafts is,

$$V = 8 \cdot 025 \sqrt{H\, a\, (T - t)}$$

H being the vertical height of flue or column of heated air in feet, T the mean temperature in the flue, and t that of the external air, both in degrees Fahr., V the velocity of the heated air in feet per second, and a the coefficient of dilatation of air for 1° Fahr. = ·002.

The results by this formula have not been found to accord with practice, no account being taken of the friction in the flue.

The following should therefore be used in preference.

$$V = \sqrt{\frac{\cdot 13\, D\, H\, (T - t)}{D + N\, L}}$$

D being the diameter of flue, and L its actual length, both in feet, H, T, t, and V being as in the previous formula.

NOTE.—For square or rectangular dues take D = the square root o fthe sectional area in square feet.

N = ·02 pipes of glazed earthenware (clean).
= ·03 shafts or flues of wood.
= ·06 flues coated with soot.

It is difficult to obtain the proper size for inlet or outlet openings by theory; the former should, however, be capable of admitting sufficient fresh air, and the latter of discharging that rendered impure by respiration and the burning of gas or oil.

Dr. Parkes and other competent authorities suggest 24 square inches per head for inlets, and the same for outlets, independent of the chimney, which

should be supplied by other means. The Commissioners on Improving the Sanitary Condition of Barracks and Hospitals, in their Report (1861) recommended the following;

Inlets:

1 square inch for every 60 cubic feet in the contents of the room.

1 square inch for every 120 cubic feet in the contents if warm air is admitted round the fire grate.

NOTE.—It may be observed that in almost every case where these proportions for inlets have been adopted in barracks, the area has been subsequently reduced to less than one-half. Too much cold air admitted to the back of a fire grate prevents the coal from burning.

Outlet shafts:

For rooms on upper floor, 1 square inch to every 50 cubic feet in the contents of the room.

Room next below, 1 square inch to every 55 cubic feet.

Room on lower floor, 1 square inch to every 60 cubic feet.

If the air is not warmed before entering the room, the inlets as well as the outlets should be placed, the former near the ceiling and the latter in the ceiling, or close to it, and they should be so constructed that cold air entering by them will not impinge on the bodies of the inmates. Fresh air introduced at or near the floor level usually passes up the chimney, and does not purify the foul air in the upper part of a room.

The greater the number of inlets in the required area, and the more they are distributed around the room, the better for the avoidance of draughts.

Other means by which air enters a room.

An ordinary well fitted window allows from 5 to 8 cubic feet of air to pass through per minute, according to the difference of temperature between the internal and external air.

Inner room doors, which are not usually so closely

fitted as windows, admit when shut from 15 to 20 cubic feet of air per minute, but when open the amount is almost unlimited.

A large quantity of air is also admitted through the walls of a building. In an experiment of Pettenkofer's an ordinary room in his house, of 2650 cubic feet space, with walls of brick, had its entire contents of air changed in one hour, when the inside temperature was 60° and the outside 32° Fahr., the doors and windows being shut; with the same temperatures, but with a good fire in the stove, the contents of the room were changed in 48 minutes; and when all the openings and crevices in doors and windows were pasted up and rendered air-tight, 1060 cubic feet of air found its way into the room.

This diffusion of air through the walls was found by Marker and Shultze to be less when the walls were of sandstone and limestone.

Diffusion of gases.—The rate at which gases intermix is inversely as the square roots of their densities.

[1] NOTE.—The force and direction of the wind has a marked effect on ventilation, therefore the size of all ventilating openings should be capable of adjustment.

Summary of Principles adopted by the Army Sanitary Commissioners on Barrack Ventilation.

1. Ventilating each room by itself, independently of any other room.

2. Providing each room with a shaft passing from the ceiling to above the roof.

3. Closing up all inlets near the floor, where such have existed, and substituting others near the ceiling, so constructed as to ensure the diffusion of the inflowing current.

4. Remodelling the fire grates, and providing a chamber at the back for heating fresh air drawn from without, and to be introduced warm above the level of the men's heads.

5. Ventilating all passages, staircases, and corridors, by shafts and perforated squares of glass, independently of the rooms.

6. Providing as nearly as possible 1200 cubic feet of fresh air per man per hour in a room space of 600 cub. feet per man.

7. Providing for the ventilation of all gas burners by funnels in the ceiling and pipes communicating from them to the open air.

WARMING.

The quantity of heat in any substance is denoted by the number of UNITS which it contains, each unit representing the quantity of heat that will raise the temperature of 1 lb. of pure water 1° Fahr. (taken at 39·1° Fahr.).

NOTE.—Heat and mechanical energy are convertible, 1 unit of heat being equal to 772 foot-pounds, and if W = any quantity of work in foot-pounds $\frac{W}{772}$ will represent the equivalent quantity of heat in units.

The heat unit of other substances is usually expressed with reference to that of water, and is called the *specific heat* of the substance.

By the following formula the number of units of heat present in any substance may be obtained.

Let S = the specific heat of the substance.
T = its temperature in deg. Fahr.
U = the number of heat units.
W = the weight of the substance in lbs.

Then

$$U = S\,T\,W$$

$$T = \frac{U}{S\,W}$$

NOTE.—In calculations of the quantities of heat required to produce given alterations of temperature where the mass is composed of various materials, substitute for the weight of each material an equivalent weight of water, then calculate as if the whole were composed of water. The equivalent weight of water is found in each case by multiplying the weight of the material by its specific heat.

Values of S.
(Regnault and others.)

	Units of Heat.		Units of Heat.
Water..	1·0000	Portland cement ..	·2000
Wood, Pine	·5174	Glass	·1977
„ Beech	·4431	Slate	·1924
„ Oak	·4042	Yorkshire paving ..	·1930
Ice	·5040	Portland stone	·1928
Coal	·2777	Brick, fire	·1917
Charcoal wood	·2415	„ stock	·1860
Aluminium	·2185	Bath stone..	·1891
Plaster of Paris.. ..	·2163	Iron, cast	·1298
Marble	·2150	„ wrought	·1138
Asphalte	·2150	Zinc	·0956
Chalk	·2149	Copper..	·0952
Lime mortar	·2109	Brass	·0939
Roman cement	·2099	Tin	·0565
Lath and plaster ..	·2067	Lead	·0314

	Pressure constant. (30 in. of Mercury.)	Volume constant.
Hydrogen gas	3·4046	2·4200
Steam	·4750	·3624
Air	·2377	·1690
Oxygen	·2182	·1542

Note.—The specific heat of all substances increases slowly as they expand, or as the temperature rises, but for temperatures of 212° and under the above are sufficiently near for practice. A unit of heat will raise the temperature of 52 cubic feet of air 1° Fahr.

Heat evolved by Respiration.—According to M. Dumas, quoted by Mr. Box, the heat developed by a man of ordinary size = 284 units per hour, 93 units of which are absorbed by the vapour formed during respiration leaving 191 units dissipated by radiation to surrounding objects and by contact of cold air, which are sufficient to maintain 331 cubic feet of air per hour at a temperature 30° above the external air.

Heat from Coal Gas.—The combustion of 1 cubic foot of coal gas, according to Morin, will produce a total of 696 heat units (Fahr.) and will raise the temperature of 36,192 cubic feet of air 1° Fahr.

Warming by Hot Water.—The circulation of hot water through pipes appears to be the most satisfactory of all means of heating a building; unlike steam, it requires very little attention, the pipes retain their heat for a long time, and the

system is perfectly safe. The following notes, founded on Mr. Hood's and other treatises on warming buildings, may be useful to those who purpose to adopt the low-pressure system of heating by water, i.e. where the temperature does not exceed 212°.

The circulation of hot water in pipes is due to the difference between the specific gravities of the water in the ascending and return pipes. The motive power is increased by adding to the vertical height of the pipes, or by allowing the water to cool a greater number of degrees before it returns to the boiler.

The length of pipe through which the water will circulate depends on the height it rises above the boiler.

A supply cistern holding about $\frac{1}{30}$th to $\frac{1}{40}$th of the quantity of water in the pipes and boiler will be sufficient.

The size of the boiler depends chiefly on the surface required to be exposed to the fire in order to maintain the heat in the pipes; a small apparatus should have more boiler surface in proportion to the length of the pipe than a large one. Four superficial feet of boiler exposed to the direct action of the fire will evaporate about 1 cubic foot of water per hour, and will heat in most cases about 200 feet in length of a pipe 4 inches diameter, and double that length of pipe 2 inches diameter. 3 feet of flue service equals only 1 foot superficial of surface exposed to the direct action of the fire. 1 square foot of grate surface will be sufficient to burn from 8 to 10 lbs. of coal per hour, depending on the draught between the bars. 1 lb. of coal in an ordinary hot-water apparatus will raise the temperature of 7000 lbs. of water on an average 1° Fahr.

Pipes 4 inches internal diameter and ¼ inch thick may be used for conservatories, &c. They should not, however, be less than 3 inches diameter. 3-inch pipes will be sufficient for public buildings, and 2-inch pipes for dwelling houses.

To equalise the resistance from friction, horizontal main pipes should be larger than the branches or vertical mains.

In fixing pipes, allowance should be made for expansion.

To permit the escape of the accumulated air, which would prevent the circulation, a small valve or tap should be inserted in the pipe at the highest point of the system, or wherever the air is likely to accumulate.

The High-Pressure System of Warming by Hot Water.

This consists of an endless wrought-iron pipe, usually about ½ inch internal diameter and ¼ inch thick, through which the water circulates at a temperature of about 350° Fahr.

Instead of a boiler, a coil of the pipe about $\frac{1}{8}$th of the total length is exposed to the action of the fire.

The expansion of the water is provided for by a larger pipe (about $2\frac{1}{2}$ inches diameter) capable of containing from 10 to 15 per cent. of the water, fixed either vertically or horizontally at the highest point of the system ; to the bottom of this pipe is fixed a tube by which the water is filled into the circulating pipe. After the whole of the air is drawn out of the pipes, and the water rises to the bottom of the expansion pipe the outlets are closed, and the circulation commences. A safety valve to the expansion pipe would, however, be an advantage.

The pipes for this system should be of the best wrought iron, and be proved to a pressure of about 3000 lbs. per square inch of the internal diameter.

To find the length of pipe required—

Let A = Air to be warmed in cubic feet per minute to the temperature T.

L = Length of pipe in feet.

T = Proposed temperature of room in deg. Fahr.

T′ = Temperature of external air.

t = Ditto of water in pipe.

Then—

$$L = A \frac{(T - T')}{(t - T)} \times \cdot 563 \text{ for 4-inch pipes,}$$

by ·751 for 3-inch pipes,
by 1·126 for 2-inch ditto,
by 2·252 for 1-inch ditto,
and by 4·504 for ½-inch ditto.

If the maximum temperature of the pipe be assumed at 200° Fahr., and the water before heating at 40°, it will take—

$4\frac{1}{2}$ hours to attain this temperature with a 4-inch pipe.
$3\frac{1}{2}$ " " 3 "
$2\frac{1}{4}$ " " 2 "

The time may be diminished by increasing the surface of the boiler exposed to the fire.

Warming by Steam.

The length for pipes when steam is used for warming may be found approximately by multiplying the length found for hot-water pipes of the same diameter, on the low-pressure system, by the following decimals.

	Temp.	
Steam at 5 lbs. above atmospheric pressure	= 228° ..	·72
Ditto 10 lbs. " "	= 240° ..	·66
Ditto 15 lbs. " "	= 250° ..	·63

To find the quantity of air to be warmed.

It is calculated by Mr. Hood that 1 square foot of glass will cool 1·279 cubic feet of air as many degrees per minute as the temperature of the room exceeds that of the external air, $\frac{1}{8}$th to $\frac{1}{10}$th being deducted from the area of the sash when of wood, but no deduction to be made when the sash is of iron.

To the quantity cooled by the glass should be added that cooled by external brick walls, 1 square foot of glass being for 9-inch walls equal to 5 square feet, for 14-inch walls 6 square feet, and for 18-inch walls 8 square feet. Thin sheet iron cools at about the same rate as glass; also must be added that supplied per minute for ventilation, heated from the temperature of the external air to that at which the room is to be maintained.

The number of cubic feet of air cooled 1° Fahr., divided by 52, will give the equivalent number of heat units.

NOTE.—The loss of heat through the walls has in practice been neglected; it depends very much on the nature and thickness of the wall. On the other hand, the heat given off by the inmates during respiration, &c., has also been omitted. Mr. Box estimates the loss of heat per square foot per hour through brick walls with one face exposed to the external air, for each degree Fahr. difference between the internal and external air, at ·275 units for walls 9 inches thick, ·182 for walls 18 inches thick, and ·108 units for walls 3 feet thick.

For ordinary stone walls 18 inches thick the loss would be ·324 units, 24 inches thick ·284 units, and for walls 3 feet thick ·228 units.

For conservatories, hot-houses, &c. It will be sufficient to allow for loss of heat by the glass only, viz., 1·279 cubic feet per superficial foot of sash, &c., cooled as many degrees per minute as the temperature of the internal exceeds that of the external air.

Coils.

As a rough approximation, according to Mr. Baldwin, each square foot of coil surface heated to 200° Fahr. will give off heat per hour equal to 2 units per degree of difference between the heat of the external air and that of the coil. The same authority states that 1 square foot of coil surface should be allowed for every 30 cubic feet of space in the room.

WATER.

The chemical composition of pure water is,

By *Volume*,

Hydrogen, 2.
Oxygen, 1.

By Weight,

Hydrogen, 1.
Oxygen, 8.

Water is never found in nature chemically pure, being always more or less mixed with air, various salts, and organic matter.

For the purpose of the hygienist, water may be divided into three classes, as follows:

1. That which contains apparently no unwholesome ingredient, and is obtained from a harmless source.

II. That which contains various salts and other ingredients apparently harmless in themselves, but indicating an impure source.

III. Water, from whatever source it is derived, which contains substances that act directly as poisons.

Class I. includes rain water, which frequently contains ammoniacal salts, compounds of sodium, chlorine, and calcium, with traces of organic matter.

In the vicinity of towns, large chemical works, &c., carbonaceous matter and sulphuric acid are found in excess.

In pure rain water the total solids seldom exceed 3 grains per gallon.

Water from wells, lakes, and rivers often contains a large proportion of salts in solution, derived from the soil; also vegetable organic matter, which, unless present in excessive quantities, are not necessarily unwholesome.

Dr. Parkes gives the following characteristics of good ordinary water, viz.:—

Chloride of sodium should not exceed		10 grains	per gallon.
Sulphate of soda	"	6	"
Carbonate of soda	"	20	"
Sulphate of lime	"	3	"
Carbonate of lime	"	14	"
Carbonate and sulphate of magnesia		3	"
Organic matter	"	$1\frac{1}{2}$	"

These should not all be present in the above proportions at the same time, as the total quantity of solid matter should never exceed 30 grains per gallon, and water, to be considered pure and wholesome, should not as a rule, contain more than 8 grains of solid matter per gallon, except that derived from chalk or limestone districts, when it should be limited to 14 grains per gallon, the excess being chiefly carbonate of lime.

Class II. Water of rivers, lakes, wells, &c., containing salts, such as nitrites, nitrates, and chloride of sodium, which result chiefly from the decomposition of organic matter, also the remains and excreta of animals, besides other impurities, which indicate that the water has been at one time or another contaminated by fæcal or sewage matter.

In waters of this class the solid matter is usually over 30 grains per gallon, and when the water is very impure it often exceeds 50 grains per gallon.

The presence of infusoria in water does not appear to have any injurious effect if it is merely an indication of vegetable organic matter, particularly water plants, but the presence of bacteria and other fresh-water algæ of the same family is in itself suspicious, as they appear to be intimately associated with putrefaction, and it is from the group to which bacteria belong that the pathogenic organisms are derived which cause disease in the human system. It is stated by Dr. Percy Frankland that "some micro-organisms are capable of multiplying largely in water of great organic purity, and even in ordinary distilled water itself." Ultimately in such a case the organisms become sterile and the water regains its purity.

Class III. Where water containing very little saline matter, say to a less extent than $\frac{1}{15000}$ part, as in rain and other soft water, is conveyed through pipes of lead or zinc (which often contains lead), or stored in cisterns formed of these metals, a portion of the metal is dissolved. The action is facilitated by the presence of organic matter, particularly if nitrates and nitrites are also present, but carbonic acid, carbonate of lime, and sulphate of lime prevent it.

It is said that 1 part of sulphate of lime (plaster of Paris) in 5000 parts of water entirely prevents lead contamination.

According to Dr. Parkes the habitual use of water containing more than $\frac{1}{20}$th grain of lead per gallon is dangerous. Pipes and cisterns of such metals as copper, lead, or zinc, should never be used where the water is likely to have a solvent action on those metals.

Water containing chlorides acts on galvanised iron. Ordinary water, if it contains lime in solution, may safely be stored in galvanised iron cisterns.

Water is sometimes poisoned from the washings of copper mines, manufacturing refuse, particularly those of chemical works, and where arsenic is used. These sources of pollution are, however, so obvious that there is seldom much danger of the water being used for domestic purposes.

Dr. Clarke's Process of Softening Water.

Bicarbonate of lime is the principal cause of hardness in water. This can be removed by adding as much lime in solution as there is pure lime in the bicarbonate of the water to be softened.

The lime added combines with one-half of the carbonic acid and becomes chalk, reducing the bicarbonate already in the water to chalk also, which being insoluble settles at the bottom of the cistern.

The Porter-Clarke process is a modification of the original method, the suspended particles of lime are removed, not by subsidence, but by filtration through a series of linen cloths in a filter press under pressure.

Another process is that of Gartlet and Huet, in which caustic soda is added to the lime and the water passed upwards and down over a series of oblique diaphragms, to accelerate the deposition of the carbonate of lime.

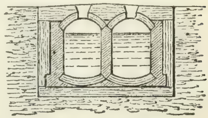
Hardness in water is measured, according to Dr. Clarke's scale, by the number of grains of chalk deposited by the lime in a gallon (70,000 grains) of water; each grain is called a *degree of hardness.*

Water of less than 5 degrees is considered soft, and over 12 degrees is considered hard. Water containing magnesium, sulphates, chlorides, and even lime in any other form than carbonate, is not affected by the process.

It is estimated that 2½ oz. of soap are required to soften every 100 gallons of water for each degree of hardness according to Dr. Clarke's scale.

Storage of Water.

Underground Tanks.—These are usually made of bricks or stone built in Portland cement or hydraulic lime mortar, and covered over with stone slabs or arches of masonry.



The bottom should as a rule be formed with inverted arches, as sketch, with or without a bed of concrete under, or with concrete alone, according to the nature of the ground.

The sides and bottom of the tank should be rendered in Portland cement well trowelled, and if there is any danger of surface water penetrating the walls, they should be backed in well-worked clay puddle, at least 12 inches thick, precaution being taken, if the tank is covered by an arch, to prevent the side walls, if thin, from being thrust outwards against the soft clay. On the other hand, it is often desirable to introduce one or more transverse division walls in cases where the ground is likely to exercise a thrust inwards.

In building a tank it is of primary importance to prevent unequal settlement, or any movement of the walls that would cause leakage.

Underground store-tanks should be constructed in two or more compartments, to admit of their being cleaned without interfering with the water supply. Each tank should have a manhole; also an inlet, outlet, and overflow pipe.

The danger of using water for domestic purposes when contaminated by sewage having been repeatedly proved, every precaution should be taken against it. Sewers should not be permitted near tanks or near the pipes which feed them; neither should the overflow pipes discharge directly into a sewer, as foul air might find its way back by that means into

the tank. The surface water of the surrounding ground should also be completely cut off from entering the tank.

The same remarks will also apply to WELLS, which should always be steined, and in porous soils puddled at the back, so as to exclude the surface water, which finds its way to a great depth and from a considerable distance.

Underground tanks may be covered over with 12 to 18 inches of sand or earth to keep the water cool in summer and to prevent it from freezing in winter.

All covered tanks should be ventilated.

Overground and Service Cisterns.—These are best formed of slate, cast or wrought iron. Slate is adapted only for small cisterns, and is difficult to keep water-tight. Cast iron corrodes less rapidly than wrought iron, but for cisterns of large size the latter should have the preference, from the ease with which the joints can be riveted and made water-tight. It will last a long time, if galvanised or kept painted.

Overflow pipes from cisterns which contain water used for cooking or drinking should, as in the case of store tanks, discharge with an open end over a trapped grating, and *never* into a soil pipe or sewer.

Water-closets should not be supplied directly from the cistern which contains the drinking water, but always from cisterns specially provided for the purpose, even where the water supply is constant and direct from the mains.

All cisterns should be covered to keep out dust and to protect the water from the action of the sun. They should also be placed where they can easily be inspected and cleaned.

Filters.—The proper use to be made of filters appears in many cases to have been overlooked, and their utility has probably also been overestimated.

The exhaustive experiments of Drs. Sims Woodhead, and Cartwright Wood have shown that most of the domestic filters approved by chemists of repute, including those containing carbon in some form or another, spongy iron, magnetic oxide, asbestos, silicious earth, and in fact any of the substances now used, are of little value as affording protection against water-borne disease.

The large filters, such as are used for the water supply of towns, have undoubtedly a beneficial action in freeing water from micro-organisms, as Dr. Percy Frankland states, to the extent of 95 to 99 per cent. Their efficiency depends on—

1. Ample storage capacity for unfiltered waters, which enables time to be given for the bacterial contents to perish.
2. The thickness of fine sand through which filtration is carried on.
3. The rate of filtration.
4. The frequency of renewal of the filter bed.

Filters act in the first instance by straining the water of some of the grosser particles of the solid matter held in suspension, but the most important effect is due to the vital action of the living organisms contained in the water which is assisted by exposure to sunlight and the separation of the water into a number of minute streams which facilitate the oxygenation of the organic matter contained in it. Water should therefore be exposed to the action of the filter during as long a time as possible.

According to the best authorities from 6 to 9 inches per hour is the maximum velocity at which water should pass through a filter of sand and gravel, unless a mere mechanical separation only of the grosser impurities is required.

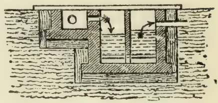
Water intended to be filtered should be received into a store reservoir, where some of the solid matter held in suspension would be allowed to subside. From this it should gradually pass through the filtering material into a service tank.

In order to prevent the disturbance of the water which has subsided to the bottom of the store reservoir by the fresh entry of water the supply pipe should empty into a receiving well, or the same purpose should be effected by other means.

The overflow pipes should be from the store reservoirs and not from the service tank.

In the settling reservoirs of the principal London Water Companies, the filtering materials adopted are from 3 to 5 feet thick, and consist of about $\frac{2}{3}$rds sand on the top, and $\frac{1}{3}$rd gravel at the bottom, the material increasing in coarseness from the top downwards. The sand should as a rule be sharp and angular and not too fine. The upper layer requires occasional cleaning. Fifty to 100 gallons of water for each superficial foot is all the Water Companies allow to pass through the filter in 24 hours.

In some cases filters for small reservoirs where the water has been permitted to rest and was exposed to sunlight might be formed as sketch, in which both downward and upward filtration takes place.



The filtering materials rest upon a grating which may be of iron or perforated slate, with a chamber underneath to retain any coarse matter that may have escaped through the first chamber. The filtering materials in the first chamber should be of sand and gravel, about 2 feet thick, varying in coarseness from the top downwards. The next chamber should have sand and gravel as before, with layers of broken shells or similar material.

Note.—When the water is received first into a store reservoir, the small receiving chamber shown in the sketch may be omitted.

Where *domestic filters* are used they should be preferably of the description known as the Pasteur-Chamberland, in which the water is made to pass

through a cylinder of biscuit porcelain. Chemically, according to Dr. Frankland, even this filter was found to have but a very trifling influence upon the composition of the water, the only change being a slight diminution in the amount of mineral matter present. It, however, has proved efficient in ridding the water of bacteria, but which it loses gradually after being in action a short time.

Animal charcoal, although formerly much used for the purpose of filtration, when deprived of phosphate and carbonate of lime by hydrochloric acid or by washing, is now considered unsafe as a filtering material, as in many cases it leaves the water more impure than it was before, owing to the fact that through oxidising the organic impurities in the water it adds both phosphates and nitrogen, which form a nidus for the growth of bacteria.

The filtration of water after the most approved method should be resorted to in all cases where solid or organic matter is supposed to exist, but it should not be relied on where the water is suspected of containing germs of disease, in which case boiling is the only safe remedy. In the author's experience water passed through a block of animal charcoal 2 inches thick was not deprived of bacteria nor of some of the smaller infusoria. Tyndall has also pointed out that plaster of Paris and even a surface of strong sulphuric acid is incapable of separating germs.

Dr. Frankland mentions a case in which an outbreak of typhoid fever at Lausen near Basle, in Switzerland, was clearly traced to drinking water that had found its way through nearly a mile of porous earth after it had been contaminated with the germs of the disease.

A case has been known where the fæcal evacuation of a single individual contaminated fatally the entire water supply of a small town.

SEWAGE.

One of the most important problems in sanitary engineering is the disposal of excreta and other refuse incident to human dwellings, particularly in towns and cities. Any attempt hitherto made to deal with the question has resulted in the adoption either of a system of pails or closed pits attached to each dwelling, and periodically emptied of their contents, or of public sewers, with such outfalls as convenience or expense indicated; these were frequently the streams and watercourses belonging to the watershed of the district: or the sewage was spread on farms, to the great danger of communicating infection to the neighbourhood. The most modern system is to collect the sewage into tanks or beds and submit it to the septic action of bacteria.

The objection to the system of storing excreta in pails and privy pits is that, fermentation being set up, gases accumulate, and poison the air; or the contents escape, and, permeating the ground, contaminate the water supply, and even render the site of the buildings pestilential.

Sewers often open up a communication between the houses, and although the sewage matter is more quickly removed by them, diseases of a fatal character may spread among the inhabitants when they are badly constructed.

The sanitary engineer should therefore arrange his works so that the propagation of disease from excreta and other refuse shall be impossible.

Privy and Cesspits.—These, though rapidly disappearing, are still used in some English and continental towns. When their adoption is unavoidable, in order to lessen the objections to them, the following precautions should be adopted, viz.:

1. They should be of masonry or brickwork on a good foundation, and built in hydraulic mortar or Portland cement. Above all, they should be perfectly water-tight; to effect which even greater precautions should be taken than in the case of tanks that hold drinking water, as in the latter case the loss of the water is perhaps the greatest evil to be sustained, except in ground saturated with impure water, which without emptying the tank, would mix with the drinking water but a leakage in a sewage tank may go on unobserved for a considerable time until the surrounding soil is saturated with sewage, and the water in the wells, if any in the neighbourhood is contaminated.

2. Privy and cesspits should be kept as far away as possible from dwelling houses, wells, water tanks, and pipes conveying drinking water.

3. They should be covered with stone flags or slate slabs, which answer better than arches, as they can be lifted completely off when required. Privy and cesspits should be ventilated, but in such a manner that foul gases cannot enter the houses or contaminate the air of frequented localities.

It should be borne in mind that the air of cesspits is often more impure than that of sewers, owing to the effect of the wind and motion of the contents preventing the gases formed in the latter from becoming stagnant.

4. The contents should not be permitted to overflow, but be removed periodically.

NOTE.—One of the principal objections to this system is, that it does not sufficiently provide for the disposal of the slops and liquid excreta, for which a separate system has usually to be provided, involving the evils which render sewers objectionable, viz., intercommunication with the houses and the pollution of rivers and watercourses.

Dry Earth System.—Allied to the system of privy and cesspits is that in which fæcal matter is deposited in pails or vessels, where it becomes mixed, as in the case of the earth closet, by a special contrivance, with a quantity of dry earth (about a

earth (about a quart at a time). The vessels when full are removed by hand, and where earth is scarce, the contents are dried for re-use; a plan which is not without danger when such epidemics as typhoid fever and cholera prevail. Fortunately the dry earth system has too many inconveniences to be generally adopted in large communities. In farm-houses, country dwellings, small villages, and as a temporary measure in large military camps, the system may, however, be adopted with advantage.

There are other methods where boxes and pails are used, which are removed daily, or when full; in some cases the contents are mixed with the ashes and refuse from the house, and in others the house refuse is otherwise disposed of.

These systems, like the privy and cesspits, do not supersede the necessity of independent means of removing slops and rain water.

Sewers.—The removal of sewage by pipes of earthenware or closed channels of masonry appears to have advantages over most other systems, and when precautions are taken to prevent the passage of foul air into the houses and to prevent the contamination of drinking water, it is probably the least objectionable of all those in use.

The following suggestions with considerable modification are based on those issued by the English Local Government Board for the use of their officers and the public:—

1. Natural streams should not be arched over to form main sewers.

2. Main sewers need not be of a capacity to take the flood water of their district, which may be passed over the surface in most cases without causing injury.

3. Main sewers should, as far as practicable, be laid out in straight lines, and follow the natural falls of the district, but

with uniform gradients from point to point. There should be side entrances or manholes, as a rule, at every change of direction in the course of the sewer, and manholes or, when the sewers are small, lampholes at every change in the gradient.

4. Duplicate systems of sewers do not appear to be required, but where drains leading to the natural streams already exist, and are not required for sewers, they should be utilised for getting rid of the storm waters.

5. Glazed earthenware or terra-cotta pipes are well adapted for sewers up to 18 inches in diameter. When sewers are required to be larger than 18 inches they should be of bricks, properly moulded to the curve, or of stonework, built in hydraulic mortar or cement. Pipes must be truly laid and securely jointed so as to be water-tight. Clay is sometimes used for jointing pipes, but is seldom satisfactory. As a rule, bitumen or Portland cement should be adopted.

House drains should in all cases be laid in a water-tight trench. If the subsoil is porous the trench should be well lined with clay puddle, or better still, with concrete. House drains, where it can be avoided, should not pass direct from the public sewers to the inside of the houses, but should terminate at an outside wall, and be disconnected from the soil pipe by an efficient trap. Where it is absolutely necessary to communicate direct with the public sewers by means of drains carried under the building, there should be a syphon, or other water trap, on the drain outside, with a ventilator placed on the house side of the trap; the portion of the drain which passes under the building should be surrounded by good Portland cement concrete.

6. Sewers of unequal areas should not join with level inverts, but the bottom of the lesser or tributary sewer should have a fall into the main equal to the difference in the diameters of the tributary sewer and main.

7. Branch pipes of earthenware, &c., should, as a rule, be less in diameter than the main on to which they join.

8. Sinks and water-closets should be placed against external walls, so that the refuse water or soil may be discharged into a drain outside the main wall.

Water-closets should never be placed where they cannot be thoroughly ventilated directly from the external air, and they should be so arranged as to be entered from a well ventilated ante-room or passage with doors to shut off the communication with the other portions of the house.

9. The solid matter of sewage should be kept saturated with water, therefore a sufficient quantity should be passed

into the drains for the purpose of flushing them. With a good water supply and sufficient fall in the drains this will generally be ensured.

10. No air should be permitted to accumulate that would be capable of forcing any trap, however slight, therefore one of the most important requirements of sewage disposal is efficient ventilation in the sewers, to permit the escape of foul air where it will not contaminate the atmosphere in populous neighbourhoods, and to prevent its passage into the houses. It must, however, be borne in mind that ventilation in the sewers means the continued evaporation of the sewage. Shafts carried above the roofs of the houses are often used, though liable to distribute microbes in the air. Ventilating openings at the surface of the ground are also used for ventilating main sewers. In streets, however, they are both dangerous and offensive unless the air from them is disinfected, which is difficult to accomplish. In towns the best positions for sewer ventilators, if used at all, is at the junction of cross streets.

Ventilating pipes, if carried above the roof of the house, should be so arranged that there would be no danger of the foul air passing in through the doors or windows, or of being sucked down the chimneys or under the slates.

Other outlet pipes, as those from sinks, baths, and ablution-basins, should discharge in the open air over the grating of a trapped cesspit.

House traps should have a seal of at least one inch of water; they should not, however, be depended upon, as the water is liable to evaporate or the trap to leak, but used merely as an extra precaution against the passage of foul air into the dwelling.

NOTE.—The idea once held that microbes may be carried through a seal of water in a trap by bubbles of gas remains unproved.

Dustbins and cesspits should also be ventilated.

The outfalls of all sewers should be free, but protected by a screen which would prevent strong winds from forcing the foul air back into houses where efficient traps are not used. Sewers liable to be affected by the rise of tides or land floods, as on the seashore or rivers, must be so arranged as to prevent any injurious backing up of the sewage.

The lower portion of any system of main sewers below the level of high water should be cut off from the upper portion, to prevent the foul air being driven up into the higher levels.

NOTE.—The question of ventilation is not one of diluting the sewer air before it enters the street, so that it may safely be inhaled. It is the

propogation of zymotic diseases which do not depend upon the *number* of infectious microbes taken into the human body, but on the conditions favourable to their growth. It has been shown that the smallest particle of the infection, or even a single microbe, may multiply itself so rapidly that the mere quantity taken into the system in the first instance is of minor importance, therefore the question of the emission of sewer air into the streets is not one of dilution at all, but of absolute exclusion. We know from the experience of the inhabitants of Caterham how small a quantity of typhoid matter will result in evil, notwithstanding its dilution in many million times its own bulk of water. Cases of typhoid fever have from time to time been reported by competent medical officers as proceeding from the air of sewer ventilators. That they are dangerous in populous localities is in accordance with experience and common sense, notwithstanding the statements made by some chemists, who appear to draw positive conclusions from purely negative evidence.

Sewage Farms.—It is difficult to believe that sewage farms are not a source by which disease may be spread. The vegetables grown on the land may be imperfectly washed, and unless well boiled are undoubtedly dangerous. The sewage matter may also pollute the wells and streams from which the water is obtained for domestic purposes, or the solid matter of the sewage in very dry weather may be blown about by the wind, and it is doubtful if the effluent water can be rendered safe from bacilli by any of the usual modes of disinfection.

BUILDING SITES.

Selection of Site.—In selecting the site for a dwelling, the preference should be given to one in which the subsoil is naturally dry and the ground elevated, so as to afford facility for getting rid of the sewage and surface water.

The best soil is supposed to be gravel or sand. Chalk and other open strata are also good, but clay, particularly if of a retentive nature, appears less likely to form a healthy site. The rain water is often retained for a long time on the surface of clayey soil, and with some kinds of clay it is absorbed, making the ground cold and damp, causing fogs, which hang over it longer than usual.

A cold, damp soil appears to have an injurious effect on most animals; in the human subject it seems to affect those in particular who are susceptible to catarrhs, rheumatism, phthisis, &c. And there is very little doubt that in other diseases damp ground exercises an unfavourable influence.

Valleys and low ground generally, whatever may be the nature of the soil, are often damp and unhealthy, owing to the water which falls on the higher ground flowing into them, bringing with it vegetable and other organic matter.

The sites to be particularly avoided are those in the neighbourhood of marshes, or other ground recently reclaimed from rivers, estuaries, or harbours, in which deposits have been formed from mud containing organic matter such as that produced when sewage is allowed to flow into the stream.

Slight eminences on the borders of marshes are also frequently unhealthy, according to their position with respect to the prevailing winds.

Dr. Parkes considers that among hills the unhealthy spots

are enclosed valleys, punch bowls, any spot where the air must stagnate, ravines, or places at their head or entrance.

In the tropics especially ravines and nullahs are to be avoided, as they are often filled with decaying vegetation, and currents of impure air frequently traverse them.

The worst ravine is a long narrow valley contracted at its outlet so as to dam up the water behind it.

In well-drained towns the nature of the subsoil is not of so much importance as in the country, owing to the buildings, roads, and pavements preventing the rain water from finding its way below the surface, and from the provision usually made for taking it rapidly into the streams and watercourses.

To render a site healthy, the level of the subsoil water should be 8 or 10 feet below the surface, and where this does not occur naturally, drains should be formed to keep it below this depth.

The raising of the subsoil water in malarious districts has been known to cause an outbreak of ague, and the lowering of it by draining has, on the contrary, caused an improvement in the health of the inhabitants.

NOTE.—Pettenkofer suggested that the lowering of the ground water is often the cause by which Enteric fever is spread in a district. Mr. Baldwin Latham supposes this to be due to the percolation of sewage into the wells in gravelly soil owing to the lowered level of the water in them.

Preparation of Site. — All soils, except when saturated with water, contain a large quantity of air, and the more porous the soil the more readily does the air pass through it. In the case of towns and habitations generally this fact has an important bearing on health, as this air may be drawn into the houses through the ground under the basement, and dangerous consequences ensue if the soil in the neighbourhood is saturated with organic matter, which frequently happens where animal excreta has been deposited on the surface, or has escaped from

sewers and other receptacles. Ground air is invariably damp, and where it is permitted to stagnate, as in the basements of houses, the growth of fungi is encouraged, and the woodwork of the floors is destroyed by dry rot; an unpleasant smell pervades the house, and the health of the occupants appears to suffer.

It is in consequence of the facility with which air and other gases traverse the ground, that old excavations or gravel pits, when filled up from the contents of ash-bins and other refuse more or less mixed with organic matter, are so objectionable in the neighbourhood of a dwelling. This is particularly the case when the ground under the basement is excavated and thus filled up, as it remains for many years a source of danger to health.

In all cases, even those in which the natural subsoil has not been disturbed, and whatever may be its nature, the ground under the basement of a dwelling should be rendered impervious to air and moisture. To effect this, nothing appears to answer so well as a layer of good concrete about 6 inches thick; probably the best is that made with well dried gravel and coal tar. Portland cement, both in the concrete and as a rendering over the surface, also answers, but no lime should be used which is not capable of resisting the effects of moisture. Stone slabs or flagging, 2 or 3 inches thick, if well bedded and jointed in good mortar or cement, and asphalte not less than ½ inch thick, if laid on concrete, may also be used, but they are expensive.

Before the adoption of any of these coverings, it is, of course, presumed that the level of the subsoil water is sufficiently below the floor of the basement.

Where the subsoil is naturally moist, the damp

should be prevented from rising through the walls by the interposition of a proper damp course, which may be of roofing slates in two thicknesses bedded in Portland cement, or of glazed earthenware such as that sold for the purpose, but the best appears to be a layer of asphalte about ½ inch thick through the thickness of the foundation walls.

The ground floor of houses where there is no basement should be raised about 2 feet above the soil, and the space below well ventilated.

Aspect.—Where there is a choice, dwellings should be so placed that as many of the rooms as possible may receive the sun's rays during some portion of the day. It is said that a south-eastern aspect is the best for the front of a house; it receives the morning sun, and is not exposed to wet in the same degree as one with a south-western aspect. The north and east are usually undesirable aspects to select, owing to the cold winds which usually blow from those points. The selection of an aspect will, however, mainly depend on the climate and the direction of the prevailing winds.

Belts of trees should be planted where required for sheltering the house, but they ought not to be placed so as to obstruct the light and air.

The *prospect* from the windows of sitting rooms should be good, whether the house be situated in the town or country, as a pleasing prospect assists considerably towards inducing a cheerful and contented state of mind, a matter of no small importance to health.

Herbage around a dwelling, according to Dr. Parkes, is always healthy, but brushwood is frequently bad, although its removal from a marsh has been known to increase the evolution of malaria, owing, it is supposed, to the disturbance and exposure of the ground.

Walls and Wall Papers.

Walls.—It is not uncommon to find that the walls of houses erected by an inferior class of builders have been built and plastered with vegetable mould or road scrapings mixed with a minimum quantity of lime, instead of mortar consisting wholly of lime and sand. By this practice a large quantity of organic matter is introduced into the walls, and even if the external moisture does not find its way through, the natural moisture in the air of rooms occupied by human beings, which is absorbed by the plaster, encourages the growth of some of the lower forms of vegetable or bacterial life that may prove detrimental to health, and must be particularly dangerous in hospitals and rooms occupied by the sick.

Note.—Few persons are aware of the extent to which the walls of a building absorb moisture from the atmosphere.

When the walls are of a much lower temperature than the surrounding air, the moisture from the latter is condensed on them and absorbed if the walls are porous. This moisture is again given back to the atmosphere as the temperature of the walls increases. In well-built houses the process is scarcely perceptible, but in those built with mortar largely containing organic matter, a close, musty odour is given off, and such buildings will always be found difficult to disinfect.

It is recommended by the best authorities connected with hygiene, that the walls of hospitals should be painted or otherwise rendered non-absorbent, in order to prevent infectious matter from lodging in them. This can only be done with safety to internal walls or those which can be kept warm, otherwise moisture would be deposited on them in damp weather.

Wall Paper.—Another and often unsuspected cause of ill-health in a dwelling is the paper used for covering the walls, owing to the poisonous nature of the colouring matter. Green papers, or those contain-

ing green in their pattern, are particularly dangerous on account of the arsenic from which the pigment is usually manufactured. In such papers arsenic is often found to the extent of from 6 to 14 grains to the superficial foot of wall, and Dr. A. S. Taylor has stated that he found some deep green papers which contained from 20 to 70 grains per superficial foot.

The cheap unglazed green paper so often to be found in the bedrooms and sitting rooms of middle and lower class dwellings is very dangerous, owing to the quantity of arsenic which it gives off in the shape of an impalpable dust. Arsenic is also said to be used in papers of other colours besides green. Copper and mercury are used in colouring wall papers; these are also poisonous, and when given off in dust, which mixes with the air of a room, produce serious consequences.

Varnished papers under the name of "Sanitary" have been introduced; they will bear a certain amount of washing with a sponge and cold water, or they may be cleaned with baker's dough.

Previous to re-papering walls the old paper should be removed, and the walls washed with water in which a small quantity of perchloride of mercury or other antiseptic has been mixed. The practice of continually placing new paper over old is most objectionable, as the latter begins to decay if damp is present in the walls.

When walls are likely to show damp on the inside, the author has found the best remedy after cutting off all the apparent sources from which damp is likely to come, is to paint the wall on the inside with two coats of good white lead paint, and letting it dry well before hanging the paper.

INFECTIOUS DISEASES AND DISINFECTION.

PREVENTIBLE DISEASES.

The following are a few of the principal diseases which may be classed under the above heading for the purposes of the Sanitary Engineer, and to which the term "Zymotic" (from a Greek word which signifies to ferment) has been applied, viz.:—

Diseases of which the infection is conveyed by means of the bowel discharges.	Enteric fever. Asiatic cholera. Choleraic diarrhœa.
Eruptive diseases of which the infectious matter is chiefly thrown off from the skin.	Small pox. Scarlet fever. Measles. Röthelin. Typhus fever. Erysipelas.
Diseases of which the infectious matter proceeds chiefly from the air passages and by means of the sputum.	Influenza. Whooping cough. Diphtheria. Croup. Croupous pneumonia. Tuberculosis.

There is now very little doubt that most, if not all, of the so-called zymotic diseases are produced by specific living organisms which belong to the great family of the Bacteria, a part of the subkingdom of vegetable life known as the Protophyta, which find a lodgment in the tissues of the body, where they grow and multiply, and produce toxic

(i.e.poisonous) substances, detrimental to their host if he is susceptible to their influence. These are called the pathogenic or disease-producing bacteria, as there are several other members of the family which have not this power.

The pathogenic group consists of bodies more or less spherical, called *micrococci*, others from their rod-like shape are known as *bacilli*, and others again from having a spiral form are called *spirilla*. All of these multiply by division, each part becoming a complete organism possessing all the functions of the original. Some of the bacilli are capable of multiplying by the production of spores which are very resistant to heat and cold or other adverse influences, and enable them to increase at a more rapid rate than the non-spore-bearing organisms, if suitable nutriment is present.

Some of the *micrococci* are exceedingly minute, measuring, according to Dr. E. Klein, not more than $\frac{1}{250000}$th of an inch in diameter, while others are much larger. The *bacilli* from which most of the pathogenic varieties are derived are also very minute, the so-called typhoid bacillus of Gaffky being not more than $\frac{1}{10000}$th of an inch in length, and *one-third* of that dimension in diameter. The *spirilla*, or so-called "comma" bacillus of Koch, is often still smaller.

Many of the bacilli are motile, possessing flagella, i.e. slender hair-like appendages which enable them to move briskly. Most of the bacteria, owing to their minute size, are easily disseminated in liquids and in the air. Naegeli, Carnelly, and others have shown, however, that they cannot of themselves quit water or moist surfaces for the atmosphere, and therefore can only get into it when borne by dried

excreta, dust or other matter capable of becoming detached by currents of air.

The diseases with which the Engineer or Town Surveyor is most concerned are enteric (i.e. typhoid) fever, Asiatic cholera, and choleraic diarrhœa, as the infectious matter is chiefly conveyed by the intestinal discharges of patients suffering from them, which, passing into the sewers reach the bodies of susceptible persons, by the impregnation of the water and other liquids used for food, or being wafted on dried excreta by currents of air, or by the wind removing particles of sewage lodged on the surface of the ground.

There was a time when the zymotic diseases were supposed to be capable of a spontaneous origin, and to originate from dust-bins, the effluvia of foul water, decaying vegetable matter, or badly smelling sewers: an idea of which some Local Authorities have not yet been able to dispossess themselves, although they do not hesitate to distribute the foul air from sewers into the atmosphere, to be inhaled by those who pass along the roads and streets, or they distribute this air on the roofs or against the sides of houses by means of so-called ventilating shafts, near to where water cisterns are placed or where food is delivered or stored.

The effect of foul air in lowering the vitality of those who inhale it is well known, by which they are rendered more susceptible of infection than when in perfect health.

Another means by which pathogenic organisms may be disseminated is the common house fly and the blow fly. These insects lay their eggs on decaying matter, and frequently pitch on the exposed skins of persons suffering from infectious diseases,

which may account for cases the cause of which is otherwise difficult to trace.

Disinfection.

The object of disinfection is to prevent the spreading of disease. Now that most of the zymotic diseases have been traced to the action of living organisms, this is usually effected by the application of substances which will either destroy them or prevent their multiplication until the complete removal of the infectious matter can be accomplished. The first are properly called *disinfectants*, the second are *antiseptics*; the latter being useful where the former, from their usually corrosive nature, would be attended with danger to animal life, or injurious to substances such as clothing, bedding, &c., which it is desirable to preserve.

Deodorants are substances which, although not necessarily disinfectants or antiseptics, will destroy or disguise offensive *odours*, and are therefore often useful in sanitary engineering; as a rule, however, the best deodorants are to be found among the disinfectants and antiseptics, as these either destroy the offending organisms or restrain their action in causing the effluvia of decomposing organic matter.

The substances which come under the above classification act in various ways; some, like the metallic salts and mineral acids, generally combine with the organic matter, or with portions of it, and by making a permanent compound, prevent the action of bacteria. Other substances, such as charcoal, condense the oxygen within their pores, and assist the destruction of the animal matter. Others, again, like permanganate of potash, give out the oxygen

which they contain in large quantities, and thus hasten the formation of carbon dioxide. Some, like chloride of lime, give out oxygen and other gases; while some more, like sulphurous acid, act by taking oxygen from the substance to be disinfected, so that there is a considerable variety in their modes of action.

Among chemicals the vapours of the following, when in sufficient strength, have been proved to render vaccine matter inert when exposed to them for twenty-four hours:—

Sulphurous Acid,
Nitric Acid,
Hydrochloric Acid.
Chlorine Gas.
Chloride of Lime.
Acetic Acid.

Most of these in their liquid form, besides several other acids and compounds of chlorine or sulphur, are probably also either antiseptics or disinfectants, among which may be mentioned picric and benzoic acids, chloride of zinc, and the sulphates of zinc and copper. They are all, however, of doubtful practical value, owing to the quantity required to make them effective.

Heat is also a powerful disinfectant. In some of the older experiments, such as those by Dr. Henry, of Manchester, it was shown that the vitality of vaccine matter was destroyed by exposure for four hours to a dry heat of 140° Fahr., or two hours to 150° Fahr., but an exposure of three hours to 120° Fahr. did not succeed in impairing the activity of vaccine lymph, and the infectious matter of scarlet fever after being exposed to a temperature of 204° Fahr. for one hour; but it is possible that the spore-bearing bacilli of some other diseases require a higher temperature, as it is known that the *spores* of most species of bacilli will stand a temperature of over 212°.

Articles of clothing and bedding are injured when exposed to a dry heat of 250°. Dr. Parsons states that for practical purposes a heat of 250°, if aided by a jet of steam for the purpose of diffusing the temperature and helping its action, may be safely applied to most textile fabrics, and will destroy the most resistant of spore-bearing bacteria. As regards

boiling water there is, however, no reliable evidence that any of the common agents of infection, such as sporeless bacilli, are able to resist a temperature of 212°, or of boiling water when exposed to it for half an hour.

Air and water are probably of themselves also destroyers of infectious matter when it is exposed to their action for a sufficient time.

NOTE.—A solution of carbolic acid, even when of considerable strength, according to Dr. Dougall's experiments, will not destroy, but preserve vaccine lymph. According to Dr. Koch's experiments, sporeless bacilli are killed in five minutes by a 5 per cent. solution of carbolic acid, though not injured by a 1 per cent. solution.

Perchloride of mercury (*corrosive sublimate*), which is a strong poison, is the best of the chemical disinfectants at present known. Sporeless bacilli are killed in a watery solution of 1 to 2000, and all spores are sterilised after a few minutes' immersion in a solution of 1 in 500 (about 1 grain to 1 oz.). Perchloride of mercury has the disadvantage of being partially neutralised by proteid or albuminous substances, therefore Dr. Klein recommends a considerable excess to be added to any material containing proteids.

The same will apply to sulphate of iron, permanganate of potash and chlorinated lime when used to disinfect discharges, such as those from typhoid fever and cholera patients, or the sputum of those suffering from tuberculosis, croupous pneumonia, and influenza.

INSTRUCTIONS FOR DISINFECTION.

Buildings, &c.—In rooms occupied by sick persons, volatile or aerial disinfectants, such as the vapours of chlorine, hydrochloric or sulphurous acid, of sufficient strength to destroy or suspend the action of infectious matter, cannot be used without injury to the patients, as none of them would be effective unless present in the air to the extent of at least 1 part in 1000, which would be too irritating for respiration. The vapour of acetic acid or chloride of lime in small quantities may, however, be of advantage in sweetening the air in the chambers of sick persons, but would be of little use in such cases either as disinfectants or antiseptics. All unnecessary articles should be removed from the room, and matters discharged from the body should be received in

a vessel containing any of the following substances in solution:—

Perchloride of mercury, $\frac{1}{6}$th oz. to 1 gallon of water.
Sulphate of iron, 2 lbs. to 1 gallon of water.
Chloride of zinc (Sir W. Burnett's fluid), 1 quart to 3 quarts of water (= 8 per cent. of solid chloride of zinc).
Carbolic acid (Calvert's No. 5), 8 fluid ounces to 1 gallon of water = 5 per cent.

NOTE.—Except the first these probably act only as antiseptics, and the proportions should be increased for the discharges from typhoid or cholera patients. As a rule the above percentages should be calculated on the whole bulk of the substance to be disinfected after adding the water.

Articles of clothing, bedding, &c., should immediately be plunged into boiling water containing carbolic acid in the above proportions, and afterwards boiled for at least half an hour; but where the proper means exist for a thorough disinfection by steam, as hereafter described, they should be submitted to that process. Boiling water or steam has the effect of fixing stains so that they will not wash out, and therefore articles that are stained should first be washed in cold water.

When rooms are vacated, their complete disinfection may be accomplished as follows:—Close all doors, windows, and other openings. Spread out all articles in the room so as to be freely exposed to the action of the disinfecting vapour. Then fumigate by either of the following processes:—

Sulphurous acid gas.—Burn in a shallow pipkin or coarse earthenware saucer, containing some live coals or a little spirits of wine, 4 ounces of sulphur for every 100 cubic feet of space in the room. This will saturate the air to the extent of nearly 3 per cent. The vessel containing the sulphur should be suspended or supported on a tongs over a pail of water to prevent accidents from the burning sulphur.

Nitrous acid gas.—For every 100 cubic feet of space place in an earthenware jar, $\frac{1}{8}$ oz. of copper filings, $\frac{1}{3}$ oz. of nitrous acid and $\frac{1}{3}$ oz. of water.

Chlorine gas.—For every 100 cubic feet of space take common salt, 1 oz.; oxide of manganese (in powder), $\frac{1}{4}$ oz.; sulphuric acid, $\frac{1}{4}$ oz.; water, $\frac{1}{4}$ oz. The water and acid to be mixed together, and then poured over the ingredients in a delf basin, which should be placed in a pipkin of hot sand; or, which is often the most convenient, for every 1000 cubic feet of space take $1\frac{1}{2}$ lb. of fresh chloride of lime and mix with 6 oz. of strong sulphuric acid.

The room should be kept closed for about twelve hours, after which the windows and doors should be thrown open, and kept so for several days to permit free ventilation.

The ceilings should be washed with water and whitened, and in very infectious diseases the paper should be removed from the walls and renewed, or the walls lime-whited before the room is again occupied.

NOTE.—Smaller quantities of the foregoing ingredients have been used, but those given are recommended by the most eminent authorities.

Chloride of lime in the proportion of 1 lb. to 2 gallons of water may be used for washing the floors, but would be too strong to mix with clothing.

For disinfecting stone or tiled floors, cover with sawdust wet with sulphuric acid.

According to Dr. Letheby and others, the use of permanganate of potass, chlorozone, and similar oxidising agents in the sick room as disinfectants is altogether fallacious, as there is no reliable evidence of their power of destroying contagia.

The best, if not the only, disinfectant is perchloride of mercury used in the proportion of *one-sixth* ounce to a gallon of water, with the addition of ¼ oz. of hydrochloric acid, which can be applied as a wash to the walls, ceilings, and woodwork by means of a painter's brush. In ordinary cases 1 part of perchloride of mercury to 5000 of water, or 1 part of chloride of zinc to 100 parts of water is sufficient for washing walls and ceilings. After about 12 hours the parts should be gone over with warm water to remove the mercury. The solution of mercury should be kept in earthenware, glass, or wooden vessels.

NOTE.—In the absence of chemical disinfectants, much may be accomplished in purifying a building by sunlight and a liberal supply of fresh air and water.

Clothing and Bedding.—These require a process of disinfection more powerful than they would undergo by exposure to the air of a room which was being fumigated by the methods previously described. They should be exposed for two or three hours in a chamber constructed for the purpose, to the fumes of burning sulphur (7 oz. for every 100 cubic feet of space), and then removed to another chamber, where they would be subjected for at least five hours to a temperature of 212° Fahr.; or a still more effectual method of destroying all bacilli and their spores is to expose the clothing and bedding in an iron chamber to the influence of steam at 250° Fahr. for five hours. Experience has proved this method to be uniformly successful.

Sewage.—The bulk and expense of the disinfectants required renders the complete disinfection of sewage in large quantities impracticable; in such cases, thorough flushing with water is probably the most efficient remedy.

For water-closets and sewage in small quantities under ordinary conditions the following may be used:—

Carbolic acid (Calvert's No. 5), 1 part to 100 of sewage (liquids and solids included).

Chloride of zinc, 1 part to 200 of sewage.

Chloride of lime, 1 lb. to 2 gallons of water for flushing water-closets.

Sulphate of iron 1 lb. to 1 gallon of water for flushing drains.

NOTE.—Sulphate of iron stains clothing, &c., therefore should only be used to disinfect sewage.

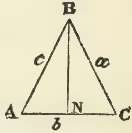
Dead Bodies.—A sheet saturated with a solution of 1 of carbolic acid to 500 parts of water and applied to the body will preserve it. So also will about 2 lbs. of carbolate powder containing 15 per cent. of carbolic acid, if placed in the bottom of the coffin; or sawdust nearly saturated with a solution of chloride or sulphate of zinc, if placed over and around the corpse.

The best method of deodorising, and probably of disinfecting, old burial grounds which are offensive, is to cover the surface to the depth of several inches with fresh earth, then to plant trees, and sow with grass.

Where the earth has become very offensive, covering with unslaked lime will tend to hasten decomposition.

MENSURATION.

Triangles.



$$\text{Area} = \frac{AC \times BN}{2}$$

$$\text{Area} = \frac{AB \times AC \times \text{Sin. } A}{2}$$

If the sides A B, B C, and A C be represented by $c\ a\ b$, and *half* their sum by s, then

$$\text{Area} = \sqrt{s\,(s-a)\,(s-b)\,(s-c)}$$

In the right angled triangle A N B, we have

$$AB^2 = AN^2 + BN^2$$

$$AB = \sqrt{AN^2 + BN^2}$$

The sides of a triangle being represented by $a\ b\ c$ as before, and the angles by A B C

$$a = \frac{b \text{ Sin } A}{\text{Sin. } B}$$

$$\text{Sin. } A = \frac{a \text{ Sin. } B}{b}$$

Two sides and the included angle given, to find the other side

$$a = \sqrt{b^2 + c^2 - 2\,b\,c \text{ Cos. } A}$$

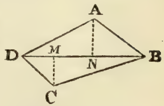
Given three sides to find the angles.

$$\text{Cos. } A = \frac{b^2 + c^2 - a^2}{2\,b\,c}$$

QUADRILATERAL OR FOUR-SIDED FIGURES.

To obtain the area of the SQUARE, RECTANGLE, RHOMBUS, or RHOMBOID, the opposite sides of which are parallel, multiply the length of the base by the perpendicular height.

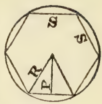
The area of a TRAPEZOID, two sides only being parallel, is found by multiplying the mean length of the parallel sides by the perpendicular distance between them.



The area of a TRAPEZIUM which has none of its sides parallel, is found by taking half the sum of the perpendiculars, multiplied by the diagonal on which they fall, or,

$$\text{Area} = \tfrac{1}{2}\, D\, B\, (A\, N + C\, M)$$

POLYGONS.



IRREGULAR POLYGONS may be divided into triangles, or trapeziums, and the areas found by the foregoing rules.

REGULAR POLYGONS are equal in area to half the sum of the sides multiplied by the perpendicular drawn from the centre.

Regular polygons are to each other as the squares of their homologous sides, therefore, if the area of a polygon whose side equals 1 (as in col. B of table) be multiplied by the square of the side of any similar polygon, the product will be the corresponding area.

The square of the diameter of a polygon (measured from opposite sides) multiplied by the number in col. A, will give the area.

The perpendicular drawn from the centre of a polygon to its side is equal to the side multiplied by the number in col. D.

The radius of a circle which circumscribes a given polygon is equal to the side multiplied by the number in col. E.

The length of the side of a given polygon is equal to the radius of its circumscribing circle multiplied by the number in col. F.

Table of Regular Polygons.

Number of Sides.	Name.	A Area when diameter of inscribed circle = 1.	B Area when side = 1.	C Length of side when perpendicular = 1.	D Perpendicular when side = 1.	E Radius of circumscribed circle when side = 1.	F Length of side when radius of circumscribed circle = 1.
3	Triangle ..	1·2990383	0·4330127	3·4641020	0·2886751	·577350	1·732051
4	Square.. ..	1·0000000	1·00 0000	2·0000000	0·5000000	·707107	1·414214
5	Pentagon ..	·9081781	1·7204774	1·4530850	0·6881910	·850651	1·175570
6	Hexagon ..	·8660254	2·5980762	1·1547005	0·8660254	1·000000	1·000000
7	Heptagon ..	·8427548	3·6339124	·9631483	1·0386207	1·152381	·867764
8	Octagon ..	·8284271	4·8284271	·8284271	1·2071068	1·306560	·765367
9	Nonagon ..	·8189330	6·1818242	·7279405	1·3737387	1·461902	·684040
10	Decagon ..	·8120553	7·6942088	·6496442	1·5388418	1·618034	·618034
11	Undecagon..	·8074727	9·3656399	·5872529	1·7028436	1·774736	·563464
12	Dodecagon ..	·8038476	11·1961524	·5358984	1·8660254	1·931850	·517638

CIRCLES.

a = Area of Circle.
c = Circumference.
d = Diameter.
D = Diameter of circumscribed circle.
s = Side of square = in area to circle.
S = Side of inscribed square.
then,

$$a = \cdot 7854\ d^2$$
$$a = \frac{c\ d}{4}$$
$$c = 3 \cdot 1416\ d$$
$$d = \ \ 31831\ c$$
$$d = 1 \cdot 128379 \sqrt{a}$$
$$d = 1 \cdot 128379\ s$$
$$D = 1\ \ 414214\ S$$
$$s = \cdot 8862269\ d$$
$$S = \cdot 2250791\ c$$
$$S = \cdot 7071068\ d$$

CIRCULAR SECTORS.

Let the diameter and radius of the circle of which the sector is a part be represented by d and r, the length of the arc and number of degrees by l and n, then

$$\text{Area} = \frac{r\ l}{2}$$

$$\text{Area} = \cdot 00218164\ d^2\ n$$

CIRCULAR SEGMENTS.

To the square of the chord C of the segment add the square of the versed sine V, and to twice the square root of the sum add the chord of half the arc *b*. Multiply the result by the versed sine and $\frac{4}{15}$ of the product will give the area,

or,

$$\text{Area} = \frac{2}{3} C\,V + \frac{V^3}{2\,C} \text{ nearly.}$$

NOTE.—When the segment is greater than a semicircle: **Find the area** of the remaining segment and deduct from the whole circle.

To find the area by the Table:

Divide the height or versed sine of the segment by the diameter of the circle of which it is a part to three places of decimals, and multiply the square of the same diameter by the number in col. A, opposite to the quotient in col. H, and the product will be the area of the segment.

NOTE.—If the quotient of the height by the diameter is greater than ·500, subtract it from 1, find the remainder in col H, and subtract the corresponding numbers in col. A from ·7854, and multiply by the square of the diameter as before.

TABLE OF THE AREAS OF THE SEGMENTS OF A CIRCLE WHOSE DIAMETER EQUALS 1.

H'ght. H.	Area. A.	H'ght. H.	Area. A.	H'ght. H.	Area. A.	H'ght. H.	Area. A.
·001	·000042	·039	·010148	·077	·027821	·115	·050165
·002	·000119	·040	·010537	·078	·028356	·116	·050804
·003	·000219	·041	·010931	·079	·028894	·117	·051446
·004	·000337	·042	·011330	·080	·029435	·118	·052090
·005	·000470	·043	·011734	·081	·029979	·119	·052736
·006	·000618	·044	·012142	·082	·030526	·120	·053385
·007	·000779	·045	·012554	·083	·031076	·121	·054036
·008	·000951	·046	·012971	·084	·031629	·122	·054689
·009	·001135	·047	·013392	·085	·032180	·123	·055345
·010	·001329	·048	·013818	·086	·032745	·124	·056003
·011	·001533	·049	·014247	·087	·033307	·125	·056663
·012	·001746	·050	·014681	·088	·033872	·126	·057326
·013	·001968	·051	·015119	·089	·034441	·127	·057991
·014	·002199	·052	·015561	·090	·035011	·128	·058658
·015	·002438	·053	·016007	·091	·035585	·129	·059327
·016	·002685	·054	·016457	·092	·036162	·130	·059999
·017	·002940	·055	·016911	·093	·036741	·131	·060672
·018	·003202	·056	·017369	·094	·037323	·132	·061348
·019	·003471	·057	·017831	·095	·037909	·133	·062026
·020	·003748	·058	·018296	·096	038496	·134	·062707
021	·004031	·059	·018766	·097	·039087	·135	·063389
·022	·004322	·060	·019239	·098	·039680	·136	·064074
·023	·004618	·061	·019716	·099	·040276	·137	·064760
·024	·004921	·062	·020196	·100	·040875	·138	·065449
·025	·005230	·063	·020681	·101	·041476	·139	·066140
·026	·005546	·064	·021168	·102	·042080	·140	·066833
·027	·005867	·065	·021659	·103	·042687	·141	·067528
·028	·006194	·066	·022154	·104	·043296	·142	·068225
·029	·006527	·067	·022652	·105	·043908	·143	·068924
·030	·006865	·068	·023154	·106	·044522	·144	·069625
·031	·007209	·069	·023659	·107	·045139	·145	·070328
·032	·007558	·070	·024168	·108	·045759	·146	·071033
·033	·007913	·071	·024680	·109	·046381	·147	·071741
·034	·008273	·072	·025195	·110	·047005	·148	·072450
·035	·008438	·073	·025714	·111	·047632	·149	·073161
·036	·009008	·074	·026236	·112	·048262	·150	·073874
·037	·009383	·075	·026761	·113	·048894	·151	·074589
·038	·009763	·076	·027289	·114	·049528	·152	·075306

SEGMENTS OF A CIRCLE—*continued.*

H'ght. H.	Area. A.	H'ght. H.	Area. A.	H'ght. H.	Area. A.	H'ght. H.	Area. A.
·153	·076026	·191	·104685	·229	·135624	·267	·168430
·154	·076747	·192	·105472	·230	·136465	·268	·169315
·155	·077469	·193	·106261	·231	·137307	·269	·170202
·156	·078194	·194	·107051	·232	·138150	·270	·171089
·157	·078921	·195	·107842	·233	·138995	·271	·171978
·158	·079649	·196	·108636	·234	·139841	·272	·172867
·159	·080380	·197	·109430	·235	·140688	·273	·173758
·160	·081112	·198	·110226	·236	·141537	·274	·174649
·161	·081846	·199	·111024	·237	·142387	·275	·175542
·162	·082582	·200	·111823	·238	·143238	·276	·176435
·163	·083320	·201	·112624	·239	·144091	·277	·177330
·164	·084059	·202	·113426	·240	·144944	·278	·178225
·165	·084801	·203	·114230	·241	·145799	·279	·179122
·166	·085544	·204	·115035	·242	·146655	·280	·180019
·167	·086289	·205	·115842	·243	·147512	·281	·180918
·168	·087036	·206	·116650	·244	·148371	·282	·181817
·169	·087785	·207	·117460	·245	·149230	·283	·182718
·170	·088535	·208	·118271	·246	·150091	·284	·183619
·171	·089287	·209	·119083	·247	·150953	·285	·184521
·172	·090041	·210	·119897	·248	·151816	·286	·185425
·173	·090797	·211	·120712	·249	·152680	·287	·186329
·174	·091554	·212	·121529	·250	·153546	·288	·187234
·175	·092313	·213	·122347	·251	·154412	·289	·188140
·176	·093074	·214	·123167	·252	·155280	·290	·189047
·177	·093836	·215	·123988	·253	·156149	·291	·189955
·178	·094601	·216	·124810	·254	·157019	·292	·190864
·179	·095366	·217	·125634	·255	·157890	·293	·191775
·180	·096134	·218	·126459	·256	·158762	·294	·192684
·181	·096903	·219	·127285	·257	·159636	·295	·193596
·182	·097674	·220	·128113	·258	·160510	·296	·194509
·183	·098447	·221	·128942	·259	·161386	·297	·195422
·184	·099221	·222	·129773	·260	·162263	·298	·196337
·185	·099997	·223	·130605	·261	·163140	·299	·197252
·186	·100774	·224	·131438	·262	·164019	·300	·198168
·187	·101553	·225	·132272	·263	·164899	·301	·199085
·188	·102334	·226	·133108	·264	·165780	·302	·200003
·189	·103116	·227	·133945	·265	·166663	·303	·200922
·190	·103900	·228	·134784	·266	·167546	·304	·201841

SEGMENTS OF A CIRCLE—*continued.*

H'ght. H.	Area. A.	H'ght. H.	Area. A.	H'ght. H.	Area. A.	H'ght. H.	Area. A.
·305	·202761	·343	·238318	·381	·274832	·419	·312054
·306	·203683	·344	·239268	·382	·275803	·420	·313041
·307	·204605	·345	·240218	·383	·276775	·421	·314029
·308	·205527	·346	·241169	·384	·277748	·422	·315016
·309	·206451	·347	·242121	·385	·278721	423	·316004
·310	·207376	·348	·243074	·386	·279694	·424	·316992
·311	·208301	·349	·244026	·387	·280668	·425	·317981
·312	·209227	·350	·244980	·388	·281642	·426	·318970
·313	·210154	·351	·245934	·389	·282617	·427	·319959
·314	·211082	·352	·246889	·390	·283592	·428	·320948
·315	·212011	·353	·247845	·391	·284568	·429	·321938
·316	·212940	·354	·248801	·392	·285544	·430	·322928
·317	·213871	·355	·249757	·393	·286521	·431	·323918
·318	·214802	·356	·250715	·394	·287498	·432	·324909
·319	·215733	·357	·251673	·395	·288476	·433	·325900
·320	·216666	·358	·252631	·396	·289453	·434	·326892
·321	·217599	·359	·253590	·397	·290432	·435	·327882
·322	·218533	·360	·254550	·398	·291411	·436	·328874
·323	·219468	·361	·255510	·399	·292390	·437	·329866
·324	·220404	·362	·256471	·400	·293369	·438	·330858
·325	·221340	·363	·257433	·401	·294349	·439	·331850
·326	·222277	·364	·258395	·402	·295330	·440	·332843
·327	·223215	·365	·259357	·403	·296311	·441	·333836
·328	·224154	·366	·260320	·404	·297292	·442	·334829
·329	·225093	·367	·261284	·405	·298273	·443	·335822
·330	·226033	·368	·262248	·406	·299255	·444	·336816
·331	·226974	·369	·263213	·407	·300283	·445	·337810
·332	·227915	·370	·264178	·408	·301220	·446	·338804
·333	·228858	·371	·265144	·409	·302203	·447	·339798
·334	·229801	·372	·266111	·410	·303187	·448	·340793
·335	·230745	·373	·267078	·411	·304171	·449	·341787
·336	·231689	·374	·268045	·412	·305155	·450	·342782
·337	·232634	·375	·269013	·413	·306140	·451	·343777
·338	·233580	·376	·269982	·414	·307125	·452	·344772
·339	·234526	·377	·270951	·415	·308110	·453	·345768
·340	·235473	·378	·271920	·416	·309095	·454	·346764
·341	·236421	·379	·272890	·417	·310081	·455	·347759
·342	·237369	·380	·273861	·418	·311068	·456	·348755

SEGMENTS OF A CIRCLE—*continued.*

H'ght. H.	Area. A.	H'ght. H.	Area. A.	H'ght. H.	Area. A.	H'ght. H.	Area. A.
·457	·349752	·468	·360721	·479	·371705	·490	·382699
·458	·350748	·469	·361719	·480	·372764	·491	·383690
·459	·351745	·470	·362717	·481	·373703	·492	·384699
·460	·352742	·471	·363715	·482	·374702	·493	·385699
·461	·353739	·472	·364713	·483	·375702	·494	·386699
·462	·354736	·473	·365712	·484	·376702	·495	·387699
·463	·355732	·474	·366710	·485	·377701	·496	·388699
·464	·356730	·475	·367709	·486	·378701	·497	·389699
·465	·357727	·476	·368708	·487	·379700	·498	·390699
·466	·358725	·477	·369707	·488	·380700	·499	·391699
·467	·359723	·478	·370706	·489	·381699	·500	·392699

CIRCULAR RING.

Let D equal the external diameter, and d equal the internal diameter, then

$$\text{Area} = \cdot 7854\ (D^2 - d^2)$$

PROPERTIES OF A CIRCLE.

A circle is equal to a triangle whose base and altitude are equal to the circumference and radius.

The LENGTH of any arc of a circle equals the number of degrees in the arc multiplied by the radius of the circle, and by ·01745329; or,

It equals *one-third* of the difference between *eight* times the chord of *half* the arc, and the chord of the whole arc nearly; or

Divide the height by the chord, and the number opposite to the quotient in the following table multiplied by the same chord will equal the length of the arc.

Table of the Length of Circular Arcs.
Chord = 1.

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
·100	1·02645	·138	1·05003	·176	1·08066	·214	1·11796
·101	1·02698	·139	1·05075	·177	1·08156	·215	1·11904
·102	1·02752	·140	1·05147	·178	1·08246	·216	1·12011
·103	1·02806	·141	1·05220	·179	1 08337	·217	1·12118
·104	1·02860	·142	1·05293	·180	1·08428	·218	1·12225
·105	1·02914	·143	1·05367	·181	1·08519	·219	1·12334
·106	1·02970	·144	1·05441	·182	1·08611	·220	1·12445
·107	1·03026	·145	1·05516	·183	1·08704	·221	1·12556
·108	1·03082	·146	1·05591	·184	1·08797	·222	1·12663
·109	1·03139	·147	1·05667	·185	1·08890	·223	1·12774
·110	1·03196	·148	1·05743	·186	1·08984	·224	1·12885
·111	1·03254	·149	1·05819	·187	1·09079	·225	1·12997
·112	1·03312	·150	1·05896	·188	1·09174	·226	1·13108
·113	1·03371	·151	1·05973	·189	1·09269	·227	1·13219
·114	1·03430	·152	1·06051	·190	1·09365	·228	1·13331
·115	1·03490	·153	1·06130	·191	1·09461	·229	1·13444
·116	1·03551	·154	1·06209	·192	1·09557	·230	1·13557
·117	1·03611	·155	1·06288	·193	1·09654	·231	1·13671
·118	1·03672	·156	1·06368	·194	1·09752	·232	1·13786
·119	1·03734	·157	1·06449	·195	1·09850	·233	1·13903
·120	1·03797	·158	1·06530	·196	1·09949	·234	1·14020
·121	1·03860	·159	1·06611	·197	1·10048	·235	1·14136
·122	1·03923	·160	1·06693	·198	1·10147	·236	1·14247
·123	1·03987	·161	1·06775	·199	1·10247	·237	1·14363
·124	1·04051	·162	1·06858	·200	1·10348	·238	1·14480
·125	1·04116	·163	1·06941	·201	1·10447	·239	1·14597
·126	1·04181	·164	1·07025	·202	1·10548	·240	1·14714
·127	1·04247	·165	1·07109	·203	1·10650	·241	1·14831
·128	1·04313	·166	1·07194	·204	1·10752	·242	1·14949
·129	1·04380	·167	1·07279	·205	1·10855	·243	1·15067
·130	1·04447	·168	1·07365	·206	1·10958	·244	1·15186
·131	1·04515	·169	1·07451	·207	1·11062	·245	1·15308
·132	1·04584	·170	1·07537	·208	1·11165	·246	1·15429
·133	1·04652	·171	1·07624	·209	1·11269	·247	1·15549
·134	1·04722	·172	1·07711	·210	1·11374	·248	1·15670
·135	1·04792	·173	1·07799	·211	1·11479	·249	1·15791
·136	1·04862	·174	1·07888	·212	1·11584	·250	1·15912
·137	1·04932	·175	1·07977	·213	1·11692	·251	1·16033

Circular Arcs—*continued.*

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
·252	1·16157	·291	1·21239	·330	1·26892	·369	1·33069
·253	1·16279	·292	1·21381	·331	1·27044	·370	1·33234
·254	1·16402	·293	1·21520	·332	1·27196	·371	1·33399
·255	1·16526	·294	1·21658	·333	1·27349	·372	1·33564
·256	1·16649	·295	1·21794	·334	1·27502	·373	1·33730
·257	1·16774	·296	1·21926	·335	1·27656	·374	1·33896
·258	1·16899	·297	1·22061	·336	1·27810	·375	1·34063
·259	1·17024	·298	1·22203	·337	1·27864	·376	1·34229
·260	1·17150	·299	1·22347	·338	1·28118	·377	1·34396
·261	1·17275	·300	1·22495	·339	1·28273	·378	1·34563
·262	1·17401	·301	1·22635	·340	1·28428	·379	1·34731
·263	1·17527	·302	1·22776	·341	1·28583	·380	1·34899
·264	1·17655	·303	1·22918	·342	1·28739	·381	1·35068
·265	1·17784	·304	1·23061	·343	1·28895	·382	1·35237
·266	1·17912	·305	1·23205	·344	1·29052	·383	1·35406
·267	1·18040	·306	1·23349	·345	1·29209	·384	1·35575
·268	1·18162	·307	1·23494	·346	1·29366	·385	1·35744
·269	1·18294	·308	1·23636	·347	1·29523	·386	1·35914
·270	1·18428	·309	1·27780	·348	1·29681	·387	1·36084
·271	1·18557	·310	1·23925	·349	1·29839	·388	1·36254
·272	1·18688	·311	1·24070	·350	1·29997	·389	1·36425
·273	1·18819	·312	1·24216	·351	1·30156	·390	1·36596
·274	1·18969	·313	1·24360	·352	1·30315	·391	1·36767
·275	1·19082	·314	1·24506	·353	1·30474	·392	1·36939
·276	1·19214	·315	1·24654	·354	1·30634	·393	1·37111
·277	1·19345	·316	1·24801	·355	1·30794	·394	1·37283
·278	1·19477	·317	1·24946	·356	1·30954	·395	1·37455
·279	1·19610	·318	1·25095	·357	1·31115	·396	1·37628
·280	1·19743	·319	1·25243	·358	1·31276	·397	1·37801
·281	1·19887	·320	1·25391	·359	1·31437	·398	1·37974
·282	1·20011	·321	1·25539	·360	1·31599	·399	1·38148
·283	1·20146	·322	1·25686	·361	1·31761	·400	1·38322
·284	1·20282	·323	1·25836	·362	1·31923	·401	1·38496
·285	1·20419	·324	1·25987	·363	1·32086	·402	1·38671
·286	1·20558	·325	1·26137	·364	1·32249	·403	1·38846
·287	1·2[illegible]696	·326	1·26286	·365	1·32413	·404	1·39021
·288	1·20828	·327	1·26437	·366	1·32577	·405	1·39196
·289	1·20967	·328	1·26588	·367	1·32741	·406	1·39372
·290	1·21202	·329	1·26740	·368	1·32905	·407	1·39548

CIRCULAR ARCS—*continued.*

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
·408	1·39724	·432	1·44039	·455	1·48320	·478	1·52736
·409	1·39900	·433	1·44222	·456	1·48509	·479	1·52931
·410	1·40077	·434	1·44405	·457	1·48699	·480	1·53126
·411	1·40254	·435	1·44589	·458	1·48889	·481	1·53322
·412	1·40432	·436	1·44773	·459	1·49079	·482	1·53518
·413	1·40610	·437	1·44957	·460	1·49269	·483	1·53714
·414	1·40788	·438	1·45142	·461	1·49460	·484	1·53910
·415	1·40966	·439	1·45327	·462	1·49651	·485	1·54106
·416	1·41145	·440	1·45512	·463	1 49842	·486	1 54302
·417	1·41324	·441	1·45697	·464	1·50033	·487	1·54499
·418	1·41503	·442	1·45883	·465	1·50224	·488	1·54696
·419	1·41682	·443	1·46069	·466	1·50416	·489	1·54893
·420	1·41861	·444	1·46255	·467	1·50608	·490	1·55090
·421	1·42041	·445	1·46441	·468	1·50800	·491	1 55288
·422	1·42222	·446	1·46628	·469	1·50992	·492	1·55486
·423	1·42402	·447	1·46815	·470	1·51185	·493	1·55685
·424	1·42583	·448	1·47002	·471	1·51378	·494	1·55854
·425	1·42764	·449	1·47189	·472	1·51571	·495	1·56083
·426	1·42945	·450	1·47377	·473	1·51764	·496	1·56282
·427	1·43127	·451	1·47565	·474	1·51958	·497	1·56481
·428	1·43309	·452	1·47753	·475	1 52152	·498	1·56680
·429	1·43491	·453	1·47942	·476	1·52346	·499	1·56879
·430	1·43673	·454	1·48131	·477	1·52541	·500	1·57079
·431	1·43856						

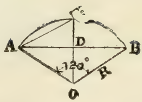
The versed sine or height of any segment of a circle being represented by v, half the chord c by s and the radius of the circle by R, we have

$$R = \frac{s^2 + v^2}{2\,v}$$

$$v = R - \sqrt{R^2 - s^2}$$

In an arc of 120° *we have*

Radius O A = ·57735 A B
,, O A = A C
Arc A C B = 1·209198 A B
,, A C B = 2·09439 R
C D = D O
$C\,D = \frac{\text{Rad.}}{2}$



$$A\,B = R\sqrt{3} = 1{\cdot}7320508\ R$$

Area of 120° segment = ·6141874 R^2

" " segment = ·2047291 $A\,B^2$

" " sector = 1·0472 R^2

$$D\,B = \frac{M\,B^2}{N\,B}$$

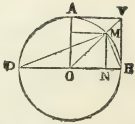
$$N\,B = \frac{M\,N^2}{D\,N}$$

$$D\,N = \frac{M\,N^2}{N\,B}$$

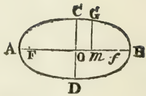
$$D\,M = \sqrt{D\,N \times N\,B}$$

$$M\,B = \sqrt{N\,B \times D\,B}$$

$$M\,N = \sqrt{D\,N \times N\,B}$$



THE ELLIPSE.



Circumference = mean of diameters × 3·1416 nearly, or more accurately

$$\text{Cir.} = 1{\cdot}5708\left(\sqrt{\frac{t^2+d^2}{2}} + \frac{t+d}{2}\right)$$

$$\text{Area} = {\cdot}7854\,d\,t$$

$$y = \frac{d}{t}\sqrt{x\,(t-x)}$$

t being taken = A B; d = C D; x = A m; $t - x$ = m B; and y = any ordinate G m.

Area of an Elliptical Segment.—Find the segment area in table for circular segments by dividing the height of the elliptical segment by the diameter of which it is a part, and this tabular area multiplied

by the product of the axes of the ellipse will be the area required.

To Find the Length of a Semi-Elliptical Arc.

Divide the height by the chord, and multiply the number opposite to the quotient in the following table by the same chord, and the product will be the length required.

Table of the Length of Elliptical Arcs.

Chord = 1.

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
·100	1·04162	·126	1·06792	·152	1·09558	·178	1·12473
·101	1·04262	·127	1·06895	·153	1·09669	·179	1·12586
·102	1·04362	·128	1·06998	·154	1·09780	·180	1·12699
·103	1·04462	·129	1·07001	·155	1·09891	·181	1·12813
·104	1·04562	·130	1·07204	·156	1·10002	·182	1·12927
·105	1·04662	·131	1·07308	·157	1·10113	·183	1·13041
·106	1·04762	·132	1·07412	·158	1·10224	·184	1·13155
·107	1·04862	·133	1·07516	·159	1·10335	·185	1·13269
·108	1·04962	·134	1·07621	·160	1·10447	·186	1·13383
·109	1·05063	·135	1·07726	·161	1·10560	·187	1·13497
·110	1·05164	·136	1·07831	·162	1·10672	·188	1·13611
·111	1·05265	·137	1·07937	·163	1·10784	·189	1·13726
·112	1·05366	·138	1·08043	·164	1·10896	·190	1·13841
·113	1·05467	·139	1·08149	·165	1·11008	·191	1·13956
·114	1·05568	·140	1·08255	·166	1·11120	·192	1·14071
·115	1·05669	·141	1·08362	·167	1·11232	·193	1·14186
·116	1·05770	·142	1·08469	·168	1·11344	·194	1·14301
·117	1·05872	·143	1·08576	·169	1·11456	·195	1·14416
·118	1·05974	·144	1·08684	·170	1·11569	·196	1·14531
·119	1·06076	·145	1·08792	·171	1·11682	·197	1·14646
·120	1·06178	·146	1·08901	·172	1·11795	·198	1·14762
·121	1·06280	·147	1·09010	·173	1·11908	·199	1·14888
·122	1·06382	·148	1·09119	·174	1·12021	·200	1·15014
·123	1·06484	·149	1·09228	·175	1·12134	·201	1·15131
·124	1·06586	·150	1·09330	·176	1·12247	·202	1·15248
·125	1·06689	·151	1·09448	·177	1·12360	·203	1·15366

ELLIPTICAL ARCS—*continued.*

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
·204	1·15484	·244	1·20380	·284	1·25538	·324	1·30924
·205	1·15602	·245	1·20506	·285	1·25670	·325	1·31061
·206	1·15720	·246	1·20632	·286	1·25803	·326	1·31198
·207	1·15838	·247	1·20758	·287	1·25936	·327	1·31335
·208	1·15957	·248	1·20884	·288	1·26069	·328	1·31472
·209	1·16076	·249	1·21010	·289	1·26202	·329	1·31610
·210	1·16196	·250	1·21136	·290	1·26335	·330	1·31748
·211	1·16316	·251	1·21263	·291	1·26468	·331	1·31886
·212	1·16436	·252	1·21390	·292	1·26601	·332	1·32024
·213	1·16557	·253	1·21517	·293	1·26734	·333	1·32162
·214	1·16678	·254	1·21644	·294	1·26867	·334	1·32300
·215	1·16799	·255	1·21772	·295	1·27000	·335	1·32438
·216	1·16920	·256	1·21900	·296	1·27133	·336	1·32576
·217	1·17041	·257	1·22028	·297	1·27267	·337	1·32715
·218	1·17163	·258	1·22156	·298	1·27401	·338	1·32854
·219	1·17285	·259	1·22284	·299	1·27535	·339	1·32993
·220	1·17407	·260	1·22412	·300	1·27669	·340	1·33132
·221	1·17529	·261	1·22541	·301	1·27803	·341	1·33272
·222	1·17651	·262	1·22670	·302	1·27937	·342	1·33412
·223	1·17774	·263	1·22799	·303	1·28071	·343	1·33552
·224	1·17897	·264	1·22928	·304	1·28205	·344	1·33692
·225	1·18020	·265	1·23057	·305	1·28339	·345	1·33833
·226	1·18143	·266	1·23186	·306	1·28474	·346	1·33974
·227	1·18266	·267	1·23315	·307	1·28609	·347	1·34115
·228	1·18390	·268	1·23445	·308	1·28744	·348	1·34256
·229	1·18514	·269	1·23575	·309	1·28879	·349	1·34397
·230	1·18638	·270	1·23705	·310	1·29014	·350	1·34539
·231	1·18762	·271	1·23835	·311	1·29149	·351	1·34681
·232	1·18886	·272	1·23966	·312	1·29285	·352	1·34823
·233	1·19010	·273	1·24097	·313	1·29421	·353	1·34965
·234	1·19134	·274	1·24228	·314	1·29557	·354	1·35108
·235	1·19258	·275	1·24359	·315	1·29603	·355	1·35251
·236	1·19382	·276	1·24480	·316	1·29829	·356	1·35394
·237	1·19506	·277	1·24612	·317	1·29965	·357	1·35537
·238	1·19630	·278	1·24744	·318	1·30102	·358	1·35680
·239	1·19755	·279	1·24876	·319	1·30239	·359	1·35823
·240	1·19890	·280	1·25010	·320	1·30376	·360	1·35967
·241	1·20005	·281	1·25142	·321	1·30513	·361	1·36111
·242	1·20130	·282	1·25274	·322	1·30650	·362	1·36255
·243	1·20255	·283	1·25406	·323	1·30787	·363	1·36399

Elliptical Arcs—*continued.*

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
·364	1 36543	·404	1·42386	·444	1·48391	·484	1·54561
·365	1·36688	·405	1·42533	·445	1·48554	·485	1·54718
·366	1·36833	·406	1·42681	·446	1·48697	·486	1·54875
·367	1·36978	·407	1·42829	·447	1·48850	·487	1·55032
·368	1·37123	·408	1·42977	·448	1·49003	·488	1·55189
·369	1·37268	·409	1·43125	·449	1·49157	·489	1·55346
·370	1·37414	·410	1·43273	·450	1·49311	·490	1·55503
·371	1·37662	·411	1·43421	·451	1·49465	·491	1·55660
·372	1·37708	·412	1·43569	·452	1·49618	·492	1·55817
·373	1·37854	·413	1·43718	·453	1·49771	·493	1·55974
·374	1·38000	·414	1·43867	·454	1·49924	·494	1·56131
·375	1·38146	·415	1·44016	·455	1·50077	·495	1·56280
·376	1·38292	·416	1·44165	·456	1·50230	·496	1·56447
·377	1·38439	·417	1·44314	·457	1·50383	·497	1·56605
·378	1·38585	·418	1·44463	·458	1·50536	·498	1·56763
·379	1·38732	·419	1·44613	·459	1·50689	·499	1·56921
·380	1·38879	·420	1·44763	·460	1·50842	·500	1·57089
·381	1·39024	·421	1·44913	·461	1·50996	·501	1·57234
·382	1·39169	·422	1·45064	·462	1·51150	·502	1·57389
·383	1·39314	·423	1·45214	·463	1·51304	·503	1·57544
·384	1·39459	·424	1·45364	·464	1·51458	·504	1·57699
·385	1·39605	·425	1·45515	·465	1·51612	·505	1·57854
·386	1·39751	·426	1·45665	·466	1·51766	·506	1·58009
·387	1 39897	·427	1·45815	·467	1·51920	·507	1·58164
·388	1·40043	·428	1·45966	·468	1·52074	·508	1·58319
·389	1·40189	·429	1·46167	·469	1 52229	·509	1·58474
·390	1·40335	·430	1·46268	·470	1·52384	·510	1·58629
·391	1·40481	·431	1·46419	·471	1·52539	·511	1·58784
·392	1·40627	·432	1·46570	·472	1·52691	·512	1·58940
·393	1·40773	·433	1·46721	·473	1·52840	·513	1·59096
·394	1·40919	·434	1·46872	·474	1·53004	·514	1·59252
·395	1·41065	·435	1·47023	·475	1·53159	·515	1·59408
·396	1·41211	·436	1·47174	·476	1·53314	·516	1·59568
·397	1·41357	·437	1·47326	·477	1·53460	·517	1·59720
·398	1·41504	·438	1·47478	·478	1·53625	·518	1·59876
·399	1·41651	·439	1·47630	·479	1·53781	·519	1·60032
·400	1·41798	·440	1·47782	·480	1·53937	·520	1·60188
·401	1·41945	·441	1·47934	·481	1·54093	·521	1·60344
·402	1·42092	·442	1·48086	·482	1·54249	·522	1·60500
·403	1·42239	·443	1·48238	·483	1·54405	·523	1·60656

Elliptical Arcs—*continued.*

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
·524	1·60812	·564	1·67087	·604	1·73477	·644	1·79964
·525	1·60968	·565	1·67245	·605	1·73638	·645	1·80127
·526	1·61124	·566	1·67403	·606	1·73799	·646	1·80290
·527	1·61280	·567	1·67561	·607	1·73960	·647	1·80454
·528	1·61436	·568	1·67719	·608	1·74121	·648	1·80617
·529	1·61592	·569	1·67877	·609	1·74283	·649	1·80780
·530	1·61748	·570	1·68036	·610	1·74444	·650	1·80943
·531	1·61904	·571	1·68195	·611	1·74605	·651	1·81107
·532	1·62060	·572	1·68354	·612	1·74767	·652	1·81271
·533	1·62216	·573	1·68513	·613	1·74929	·653	1·81435
·534	1·62372	·574	1·68672	·614	1·75091	·654	1·81599
·535	1·62528	·575	1·68831	·615	1·75252	·655	1·81763
·536	1·62684	·576	1·68990	·616	1·75414	·656	1·81928
·537	1·62840	·577	1·69149	·617	1·75576	·657	1·82091
·538	1·62996	·578	1·69308	·618	1·75738	·658	1·82255
·539	1·63152	·579	1·69467	·619	1·75900	·659	1·82419
·540	1·63309	·580	1·69626	·620	1·76062	·660	1·82583
·541	1·63465	·581	1·69785	·621	1·76224	·661	1·82747
·542	1·63623	·582	1·69945	·622	1·76386	·662	1·82911
·543	1·63780	·583	1·70105	·623	1·76548	·663	1·83075
·544	1·63937	·584	1·70264	·624	1·76710	·664	1·83240
·545	1·64094	·585	1·70424	·625	1·76872	·665	1·83404
·546	1·64251	·586	1·70584	·626	1·77034	·666	1·83568
·547	1·64408	·587	1·70745	·627	1·77197	·667	1·83733
·548	1·64565	·588	1·70905	·628	1·77359	·668	1·83897
·549	1·64722	·589	1·71065	·629	1·77521	·669	1·84061
·550	1·64879	·590	1·71225	·630	1·77684	·670	1·84226
·551	1·65036	·591	1·71286	·631	1·77847	·671	1·84391
·552	1·65193	·592	1·71546	·632	1·78009	·672	1·84556
·553	1·65350	·593	1·71707	·633	1·78172	·673	1·84720
·554	1·65507	·594	1·71868	·634	1·78335	·674	1·84885
·555	1·65665	·595	1·72029	·635	1·78498	·675	1·85050
·556	1·65823	·596	1·72190	·636	1·78660	·676	1·85215
·557	1·65981	·597	1·72350	·637	1·78823	·677	1·85379
·558	1·66139	·598	1·72511	·638	1·78986	·678	1·85544
·559	1·66297	·599	1·72672	·639	1·79149	·679	1·85709
·560	1·66455	·600	1·72833	·640	1·79312	·680	1·85874
·561	1·66613	·601	1·72994	·641	1·79475	·681	1·86039
·562	1·66771	·602	1·73155	·642	1·79638	·682	1·86205
·563	1·66929	·603	1·73316	·643	1·79801	·683	1·86370

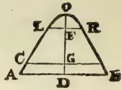
Elliptical Arcs—*continued.*

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
·684	1·86535	·724	1·93204	·764	1·99989	·804	2·06901
·685	1·86700	·725	1·93373	·765	2·00160	·805	2·07076
·686	1·86866	·726	1·93541	·766	2·00331	·806	2 07251
·687	1·87031	·727	1·93710	·767	2·00502	·807	2·07427
·688	1·87196	·728	1·93378	·768	2·00673	·808	2·07602
·689	1·87362	·729	1·94046	·769	2·00844	·809	2·07777
·690	1·87527	·730	1·94215	·770	2·01016	·810	2·07953
·691	1·87693	·731	1·94383	·771	2·01187	·811	2·08128
·692	1·87859	·732	1·94552	·772	2·01359	·812	2·08304
·693	1·88024	·733	1·94721	·773	2·01531	·813	2·08480
·694	1·88190	·734	1·94890	·774	2·01702	·814	2·08656
·695	1·88356	·735	1·95059	·775	2·01874	·815	2·08832
·996	1·88522	·736	1·95228	·776	2·02045	·816	2·09008
·697	1·88688	·737	1·95397	·777	2·02217	·817	2·09198
·698	1·88854	·738	1·95566	·778	2·02389	·818	2·09360
·699	1·89020	·739	1·95735	·779	2·02561	·819	2·09536
·700	1·89186	·740	1·95994	·780	2·02733	·820	2·09712
·701	1·89352	·741	1·96074	·781	2 02907	·821	2·09888
·702	1·89519	·742	1·96244	·782	2·03080	·822	2·10065
·703	1·89685	·743	1·96414	·783	2·03252	·823	2·10242
·704	1·89851	·744	1·96583	·784	3·03425	·824	2·10419
·705	1·90017	·745	1·96753	·785	2·05598	·825	2·10596
·706	1·90184	·746	1·96923	·786	2 03771	·826	2·10773
·707	1·90350	·747	1·97093	·787	2·03944	·827	2·10950
·708	1·90517	·748	1·97262	·788	2·04117	·828	2·11127
·709	1·90684	·749	1·97432	·789	2·04290	·829	2·11304
·710	1·90852	·750	1·97602	·790	2·04462	·830	2·11481
·711	1·91019	·751	1·97772	·791	2·04635	·831	2·11659
·712	1·91187	·752	1·97943	·792	2·04809	·832	2·11837
·713	1·91355	·753	1·98113	·793	2·04983	·833	2·12015
·714	1·91523	·754	1·98283	·794	2·05157	·834	2·12193
·715	1·91691	·755	1·98453	·795	2·05331	·835	2·12371
·716	1·91859	·756	1·98623	·796	2 05505	·836	2·12549
·717	1·92028	·757	1·98794	·797	2·05679	·837	2·12727
·718	1·92195	·758	1·98964	·798	2·05853	·838	2·12905
·719	1·92363	·759	1·99134	·799	2·06027	·839	2·13083
·720	1·92531	·760	1·99305	·800	2·06202	·840	2·13261
·721	1·92706	·761	1·99476	·801	2·06377	·841	2·13439
·722	1·92868	·762	1·99647	·802	2·06552	·842	2·13618
·723	1·93036	·763	1·99818	·803	2 06727	·843	2·13797

ELLIPTICAL ARCS—*continued.*

H'ght.	Length.	H'ght.	Length.	H'ght.	Length.	H'ght.	Length.
·844	2·13976	·883	2·21022	·922	2·28170	·961	2·35431
·845	2·14155	·884	2·21205	·923	2·28354	·962	2·35621
·846	2·14334	·885	2·21388	·924	2·28537	·963	2·35810
·847	2·14513	·886	2·21571	·925	2·28720	·964	2·36000
·848	2·14692	·887	2·21754	·926	2·28903	·965	2·36191
·849	2·14871	·888	2·21937	·927	2·29086	·966	2·36381
·850	2·15050	·889	2·22120	·928	2·29270	·967	2·36571
·851	2·15229	·890	2·22303	·929	2·29453	·968	2·36762
·852	2·15409	·891	2·22486	·930	2·29636	·969	2·36952
·853	2·15589	·892	2·22670	·931	2·29820	·970	2 37143
·854	2·15770	·893	2·22854	·932	2·30004	·971	2·37334
·855	2·15950	·894	2·23038	·933	2·30188	·972	2·37525
·856	2·16130	·895	2·23222	·934	2·30373	·973	2·37716
·857	2·16309	·896	2·23406	·935	2·30557	·974	2·37908
·858	2·16489	·897	2·23590	·936	2·30741	·975	2·38100
·859	2·16668	·898	2·23774	·937	2·30926	·976	2·38291
·860	2·16848	·899	2·23958	·938	2·31111	·977	2·38482
·861	2·17028	·900	2·24142	·939	2·31295	·978	2·38673
·862	2·17209	·901	2·24325	·940	2·31479	·979	2·38864
·863	2·17389	·902	2·24508	·941	2·31666	·980	2·39055
·864	2·17570	·903	2·24691	·942	2·31852	·981	2·39247
·865	2·17751	·904	2·24874	·943	2·32038	·982	2·39439
·866	2·17932	·905	2·25057	·944	2·32224	·983	2·39631
·867	2·18113	·906	2·25240	·945	2·32411	·984	2·39823
·868	2·18294	·907	2·25423	·946	2·32598	·985	2·40016
·869	2·18475	·908	2·25606	·947	2·32785	·986	2·40208
·870	2·18656	·909	2·25789	·948	2·32972	·987	2·40400
·871	2·18837	·910	2·25972	·949	2·33160	·988	2·40592
·872	2·19018	·911	2·26155	·950	2·33348	·989	2·40784
·873	2·19200	·912	2·26338	·951	2·33537	·990	2·40976
·874	2·19382	·913	2·26521	·952	2·33726	·991	2·41160
·875	2·19564	·914	2·26704	·953	2·33915	·992	2·41362
·876	2·19746	·915	2·26888	·954	2·34104	·993	2·41556
·877	2·19928	·916	2·27071	·955	2·34293	·994	2·41749
·878	2·20110	·917	2·27254	·956	2·34483	·995	2·41943
·879	2·20292	·918	2·27437	·957	2·34673	·996	2·42136
·880	2·20474	·919	2·27620	·958	2·34862	·997	2·42329
·881	2·20657	·920	2·27803	·959	2·35051	·998	2·42522
·882	2·20839	·921	2·27987	·960	2·35241	·999	2·42715

Parabola.



$$\text{Area} = \tfrac{2}{3}\,OD \times AB$$

$$FO = \tfrac{1}{4}\,LR = \frac{CG^2}{4\,OG}$$

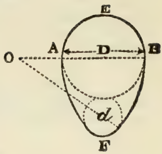
If $m =$ the focal distance O F; $y =$ ordinate C G; and $x =$ the abscissa O G, then

$$y = \sqrt{4\,m\,x}$$

from which the curve may be constructed.

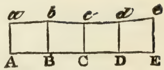
$$\text{Length of arc} = 2\sqrt{y^2 + \tfrac{4}{3}x^2} \text{ nearly.}$$

Egg-Shaped Sewers.



Diameter A B = D
E F = D + d
O B = E F.
Area = 1·14853′ D².
Area of part below A B = ·755831 D².
Area of part above A B = ·3927 D².
The perimeter or length A E B F = 3·960696 D.
The perimeter of part A F B = 2·3899 D.

The Area of Irregular Figures.



Measure the heights or ordinates A a, B b, C c, &c., at equal distances apart, then

The area will equal the mean of the extreme ordinates (as A a and E e) added to the sum of the intermediate ones, and multiplied by the whole length of the figure divided by the number of ordinates less one.

Cubes, &c.

The SOLIDITY of cubes, parallelopipedons, and prisms is found by multiplying the area of the base by the perpendicular height.

Cylinders.

Solidity = area of base × perpendicular height.
Surface = circumference × length + twice the area of the base.
Capacity of a cylinder 1 foot diameter and 1 foot long = 4·8947 imperial gallons.

Cylindrical Ring.

t = thickness of ring; d = inner diameter.
Solidity $= 2 \cdot 4674\, t^2 (d + t)$.
Surface $= 9 \cdot 8696\, t\,(d + t)$.

Pyramids and Cones.

Solidity = area of base multiplied by $\frac{1}{3}$rd of the perpendicular height.

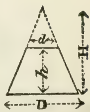
Surface = slant height multiplied by half the girth at base, to which add the area of base.

Frustums of Pyramids and Cones.

A a = areas of the ends.
h = the perpendicular height.

$$\text{Solidity} = \frac{h}{3}(\sqrt{A\,a} + A + a).$$

Surface = mean circumference or girth multiplied by the slant height, to which add the areas of the ends.



To find the height, H, of a cone from which a given frustum has been cut; let h = height of frustum; D = diameter at base; d = diameter at top, then

$$H = \frac{D\,h}{D - d}$$

Wedges.

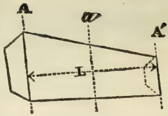
If b and L = breadth and length of back; E = length of edge; and h = perpendicular distance between the back and edge, we have

$$\text{Solidity} = \frac{b\,h\,(2\,L + E)}{6}$$

If the edges are parallel but of different lengths, the solidity = $\frac{1}{3}$rd of the sum of the edges multiplied by the area of a section taken at right angles to them.

Prismoid.

If A and $A' =$ areas of end sections, $a =$ area of middle section, and $L =$ the length,

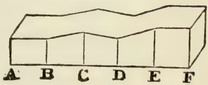


$$\text{Solidity} = \frac{L(A + 4a + A')}{6}$$

Note.—The sections are to be taken parallel to each other, and the area of the middle section to be calculated from the mean dimensions, and not by averaging the areas of the ends.

Cuttings and Embankments.

Divide the figure into any number of parallel and equidistant sections, as at A, B, C, D, E, and F, find the area of each, and also of a section midway between them, as explained in the previous note; then



To the end sections, as at A and F, add twice the sum of the sections taken at the equidistant parts, B, C, D, and E, and four times the sum of the intermediate sections; this sum multiplied by one-sixth of the length of one of the parts, as A, B, will give the solid content.

Note.—Railway cuttings and embankments are usually calculated by the prismoidal formula. In ground where the surface winds, short lengths of cutting or embankment should be taken to obtain even approximate results.

To measure the solidity of earthwork over large areas of irregular depth.—Divide the surface into triangles, and multiply the horizontal area of each by one-third of the sum of the vertical depths taken at the angles, and the result will equal the solidity.

Note.—The surfaces of the triangles must be true planes, or they must be taken so small as to approximate to planes.

Globes or Spheres.

A globe is equal to a pyramid or cone whose base and altitude are equal to the surface and radius.

If $d =$ diameter,

Surface $= 3{\cdot}1416\, d^2$.

Solidity $= {\cdot}5236\, d^3$.

NOTE.—The solidity of a sphere equals $\frac{2}{3}$rds of the solidity of its circumscribing cylinder, and the curved surface equals the circumference of the same cylinder multiplied by its height.

The surface of a sphere multiplied by *one-sixth* of its diameter will equal the solidity.

SEGMENT OF A SPHERE.

Let $d =$ diameter of the whole sphere, and $h =$ height of segment.

Solidity $= \cdot 5236\, h^2\,(3\,d - 2\,h)$; or

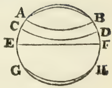
if $r =$ radius of base of segment,

Solidity $= \cdot 5236\, h\,(3\,r^2 + h^2)$.

Convex surface $= \mathrm{C}\,h$,

C being the circumference of the whole sphere from which the segment was taken.

THE FRUSTUM OR ZONE OF A SPHERE.



R = Radius of greater end, C D.
r = Radius of lesser end, A B.
h = Height of frustum.

$$\text{Solidity} = 1 \cdot 5708\, h \left(\mathrm{R}^2 + r^2 + \frac{h^2}{3}\right)$$

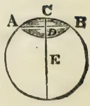
THE MIDDLE ZONE OF A SPHERE.

D = Diameter, E F, of whole sphere, and $h =$ height or thickness of zone.

Solidity $= \cdot 7854\, h\,(\mathrm{D}^2 - \frac{1}{3}\,h^2)$.

The surface is found in the same manner as for the segment of a sphere.

CIRCULAR SPINDLES.



Let $a =$ area of the generating circular segment A, C, B; $l =$ length A B; and $s =$ D E, or the radius minus the versed sine D C.

Solidity $= \cdot 5236\,(l^3 - 12\,a\,s)$.

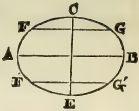
Surface $= 6 \cdot 2832\,(l\,r - s\,e)$,

r being the radius of the generating circle, and e the length of the arc, A, C, B.

Spheroid.

If D = the fixed axis, d = the revolving axis,

$$\text{Solidity} = \cdot 5236\, D\, d^2.$$



Note.—A prolate spheroid revolves on its longer axis; an oblate spheroid on its shorter axis.

Segment of a Spheroid.

h = height of segment and $D\ d$, as before.

$$\text{Solidity} = \frac{\cdot 5236\, d^2\, h^2\,(3\,D - 2\,h)}{D^2}$$

The Middle Zone of a Spheroid.

D = Middle diameter A B; d = that of the ends F G.
h = height or distance between the ends.

$$\text{Solidity} = \cdot 2618\, h\,(2\,D^2 + d^2).$$

Note.—This is similar in shape to a cask of the *first* variety.

Parabolic Conoid.

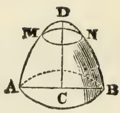
If D = diameter at base. and h = height,

$$\text{Solidity} = \cdot 3927\, h\, D^2.$$

Frustum of a Parabolic Conoid.

d = diameter at upper end M N.

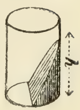
$$\text{Solidity} = \cdot 3927\, h\,(D^2 + d^2)$$



Note.—The double frustum of a parabolic conoid is similar to a cask of the *third* variety, in which D represents the bung diameter, and d that of the head.

Hoof of a Cylinder.

a = Area of base of hoof.
C = Chord of base.
h = Height of hoof.
R = Radius of cylinder.
v = Versed sine of base.



When v is greater than R,

$$\text{Solidity} = \frac{h}{v}\left\{\frac{C^3}{12} - a\,(v - R)\right\}$$

When v is less than R,

$$\text{Solidity} = \frac{h}{v}\left\{\frac{C^3}{12} + a\,(R - v)\right\}$$

When the section passes through the centre of the base, i. e. when the base of the hoof is a semicircle, C being $= 2\,R$ and $v = R$.

Then
$$\text{Solidity} = \frac{2}{3}\,R^2 h$$

NOTE.—When the section passes obliquely through the opposite sides of the cylinder, the solidity = the mean height multiplied by the area of the base.

PARABOLIC SPINDLE.

$D =$ diameter at the middle, and $l =$ the length.

$$\text{Solidity} = \cdot 41888\ D^2\, l.$$

THE MIDDLE FRUSTUM OF A PARABOLIC SPINDLE.

Solidity $= \cdot 2618\, l\ (2\,D^2 + d^2 - \cdot 4\,(D - d)^2)$; d being taken equal to the diameter at the end.

NOTE.—This is similar to a cask of the *second* variety.

REGULAR SOLIDS.

To find the surface and solid contents of any of the regular bodies:

Multiply the tabular *area* by the *square* of the linear edge of the solid, and the product will equal the surface; and

Multiply the tabular *solidity* by the *cube* of the linear edge for the solidity.

No. of Sides.	Name.	Area.	Solidity.
4	Tetrahedron	1·7320508	0·1178513
6	Hexahedron	6·0000000	1·0000000
8	Octahedron	3·4641016	0·4714045
12	Dodecahedron	20·6457288	7·6631189
20	Icosahedron	8·6602540	2·1816950

Gauging of Casks.

Let $M =$ The middle or bung diameter.
$D =$ Diameter at end.
$l =$ Length of cask.

Casks of the first variety,—considerably curved.

Capacity in imp. galls. $= \cdot 0009442\, l\, (2\,M^2 + D^2)$.

Casks of the second variety,—moderately curved.

$$\text{Capacity in imp. galls.} = \cdot 0009442\, l \left((2\,M^2 + D^2) - \tfrac{2}{5}\,(M - D)^2 \right)$$

Casks of the third variety,—with very little curve.

Capacity in imp. galls. $= \cdot 0014162\, l\, (M^2 + D^2)$.

Hutton's rule for casks of any form.

$$\text{Capacity in imp. galls.} = \cdot 00003147\, l\, (39\,M^2 + 25\,D^2 + 26\,M\,D).$$

Ullage of Casks.

To find the contents of a lying cask when partly full:

Divide the depth of the liquid in inches by the bung diameter in inches; and if the quotient is less than ·5, deduct from it one-fourth of the difference; but if the quotient exceeds ·5, add one-fourth of that excess to it, and multiply either the remainder in the former case, or the sum in the latter, by the whole capacity of the cask, and the product is the content in imperial gallons.

To find the content of a standing cask when partly full:

Divide the depth of the liquid by the length of the cask, both in inches; then if the quotient is less than ·5, subtract from it one-tenth part of the difference, but if greater than ·5, add one-tenth of its excess, and multiply the remainder in the former case, or the sum in the latter, by the whole capacity of the cask, and the product is the content in imperial gallons.

Timber Measure.

A tree is not usually considered to be timber, unless the stem measures 24 inches in circumference. The conventional method of measuring round or unsquared timber is as follows:

To find the cubic contents :

Gird the timber round the middle with a string, and one-fourth of this girth squared and multiplied by the length will equal the solidity. If the circumference is taken in inches and the length in feet, divide by 144 to obtain the result in cubic feet.

NOTE.—If the tree is very irregular or tapers much, divide it into several lengths and measure each separately.

TABLE FOR MEASURING TIMBER.

Quarter Girth.	Area.	Quarter Girth.	Area.	Quarter Girth.	Area.	Quarter Girth.	Area.
inches.	feet.	inches.	feet.	inches.	feet.	inches.	feet.
3	·063	7½	·390	12	1·000	16½	1·890
3¼	·073	7¾	·417	12¼	1·042	16¾	1·948
3½	·085	8	·444	12½	1·085	17	2·006
3¾	·093	8¼	·472	12¾	1·129	17¼	2·066
4	·111	8½	·501	13	1·174	17½	2·126
4¼	·125	8¾	·531	13¼	1·219	17¾	2·187
4½	·140	9	·562	13½	1·265	18	2·250
4¾	·157	9¼	·594	13¾	1·313	18½	2·376
5	·174	9½	·626	14	1·361	19	2·506
5¼	·192	9¾	·659	14¼	1·410	19½	2·640
5½	·210	10	·694	14½	1·460	20	2·777
5¾	·230	10¼	·730	14¾	1·511	20½	2·917
6	·250	10½	·766	15	1·562	21	3·062
6¼	·272	10¾	·803	15¼	1·615	21½	3·209
6½	·294	11	·840	15½	1·668	22	3·362
6¾	·317	11¼	·878	15¾	1·722	22½	3·516
7	·340	11½	·918	16	1·777	23	3·673
7¼	·364	11¾	·959	16¼	1·833	24	4·000

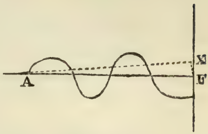
If the bark is on the tree, a deduction should be made from the girth as follows:

For oak, old and thick barked .. .. .. = $\frac{1}{10}$th of girth.
„ young and thin barked .. .. = $\frac{1}{12}$th „
elm, pine, and fir .. .. = $\frac{1}{15}$th „
ash and beech .. .. = $\frac{1}{35}$th „

The Partition of Land, &c.

To substitute a straight line for an irregular one, so that the areas on each side shall remain the same:

From the proposed origin A, of the straight line required, measure an assumed or trial line as A X, approximating to the true one as near as possible.



Then take the sum of the areas on the right and also on the left of this line and divide twice the difference by the length of the trial line, and the quotient will be the perpendicular distance from the end X, to which the required line A F must be drawn, in order that the areas on both sides, bounded by the irregular one, may be equal.

The perpendicular to be drawn on that side of the line A X, where the areas are greatest.

THE MEASUREMENT OF BUILDERS' WORK.

The operations comprised in builders' measurements are—

1. Taking the dimensions.
2. Squaring, abstracting, and bringing the quantities into bill.
3. The preparation of the estimate, which consists in attaching prices to the items of the bill, moneying them out, and casting up the result.

The dimensions are taken in feet and inches, either from the actual work itself, termed "measuring up," or from the drawings before the work is executed, which is termed "taking out the quantities," the mode of proceeding being nearly the same in both cases.

Commence by writing in the dimension book, or on paper ruled for the purpose, the name of the work and that of the surveyor who attends on the opposite side, and the date; also the number and description of the drawings.

NOTE.—A surveyor should not take off quantities from an unfinished drawing, and he should be able to certify, in case of dispute, that the drawings from which the dimensions were taken have not been tampered with.

The several parts of the work may be taken in the order most convenient, but the system once adopted should as a rule always be followed, and the dimensions entered in the following order, viz.:—

1st. The length.
2nd. The width.
3rd. The depth or thickness.

Observing always to enter *vertical* dimensions last.

Thus—A *wall* should have its length entered first: next, its thickness; and lastly, its height. An *arch* should have its length entered first; next, its girth; and lastly, its thickness. A *stone*, its length on the face; next, its depth in the wall; and lastly, its height. A *door* should have its width always entered before its height.

When several lengths have to be added together, note the process in the margin of the dimension book, technically termed "on waste."

Give a description of the material, workmanship, and position of the work.

NOTE.—As the limits of this Handbook prohibit a full description of the method of measuring Builders' Work, students who wish to become masters of the subject are referred to Leaning's 'Practical Treatise on Quantity Surveying.'

EXCAVATORS' WORK.

General Excavations.

At per cubic yard.

Take the excavation as digging and throwing out, under 6 feet in depth, and wheeling under 1 run (= 20 yards), or basketing where wheeling is impracticable.

When the depth exceeds 6 feet, or the distance to be removed is more than 1 run, or if the road is inclined, give the particulars; also describe the nature of the soil.

If the surface mould has to be removed (usually to the depth of 12 inches), it should be taken by the yard super. as digging and depositing for reuse.

Trenches for Foundations.

At per cubic yard.

Trenches for foundations are usually kept separate from the general excavation, and described as "*digging trenches for foundations, including part filled in and rammed after the walls are built and the remainder removed,*" or the digging and removing is taken by itself, and the digging, filling, and ramming made a distinct item.

Allow a width of 6 inches on each side of the footings to give the bricklayer room to work. Where there are concrete foundations allow only the net width of the concrete.

Trenches in a basement should be so described, also grubbing up old foundations (if any).

Trenches for Drains, Pipes, &c.

At per yard run.

State the depth and size of pipe or drain.

Sometimes, where large or deep trenches are required, the excavation is measured by the yard cube, in which case it is usual to take the bottom of the trench about 12 inches wider than the external diameter of the pipe.

Note.—No excavation except in rock or chalk is supposed to stand vertically, and unless it is to be strutted an addition for sloping sides should be taken to the digging. Three inches for every foot in depth will generally be sufficient to allow on each side.

Shoring and Strutting, &c.

At per foot superficial.

When the excavation is deep (over 4 feet) and the soil loose, instead of allowing for slopes, the length and depth of

the sides should be measured for shoring and planking. Narrow trenches, under 6 feet wide, should be measured at per foot run, and described as strutting and planking to sides of narrow excavations, according to the depth and width.

Wells.

At per yard cube.

Measure as before, and state the diameter of the well, depth, nature of soil, and distance to be removed.

Wells that are to be steined are usually numbered and described as "*digging and steining*"; gear, tackle, buckets, and stages included. Give the depth and diameter in clear of the steining, describe the nature of the steining, whether laid in mortar, cement, or left dry, and state if puddle be required. Take curbs and the permanent pumps extra.

Pumping.

Wherever pumping is likely to be required it should be stated.

Clay Puddle over Vaults and Arches.

At per yard superficial.

State the height of the arches above the ground, and the thickness of the puddle required. If more than 12 inches thick, it should be taken at *per cubic yard*.

Pile Driving.

Number the piles, state the full length in feet, the kind of timber, the scantling, and the length to be driven.

Number the ringing, pointing, shoeing, and cutting off the heads when driven, and state the weight of the rings and shoes.

Concrete.

Concrete in foundations or otherwise, in thicknesses of 12 inches or over, is charged at per cubic yard.

Concrete under pavings or hearths, or where the thickness is less than 12 inches, is taken at per yard superficial.

When concrete is filled in over arches, or lifted to a height above the ground, it should be so described, and the height stated.

Expansion boards are sometimes necessary to concrete backing; they should be taken at *per foot run*, and the labour in fixing and removing described. After removal, the space has to be filled in with grout.

BRICKLAYERS' WORK.

BRICKWORK IN GENERAL.

At per rod reduced.

Measure brickwork superficially in feet and inches, and state the number of bricks in thickness.

In very thick walls, or where the thickness is irregular, it is sometimes more convenient to take all the dimensions in feet and inches, and afterwards to reduce them to the standard thickness of 1½ brick. Walls under one brick thick should be kept separate.

Circular brickwork is classified according to curvature into "flat sweep" when above, and "quick sweep" when below 25 feet radius; in the former the face only to be taken as extra; in the latter the radius should be given, and the brickwork described as being circular, in addition to taking the circular face, more labour being entailed in the body of the wall. Brickwork if over 60 feet from the ground, should be kept separate.

Walls built with a batter should be kept separate, but not if only the face batters; in either case a superficial measurement of "Extra to battering face" should be taken.

Take all deductions for openings, &c., as they appear.

Window sills, door sills, stone, or woodwork under 6 inches in height are not to be deducted.

Wall plates, when on brickwork, are sometimes measured in if they do not exceed 3 inches in height, to pay for bedding and the trouble of fixing. The better way is to take the bedding, &c., by the foot run.

No allowance in quantity is to be made for small or difficult works. The labour on them should be charged separately.

Measure all cuttings over 6 inches wide by the foot superficial, and under 6 inches wide by the foot run; state if fair cut and rubbed, or rough, and whether to splays, rakes, or otherwise. It is usual to measure the "face" of brickwork from 3 inches below the ground line at per foot superficial, in addition to the cubic quantity, except where left rough, as against earthwork, &c. It should be described as "Extra to face of selected (or superior-made bricks, as the case may be), including pointing."

Reveals to doors and window openings are kept separate when plastered or different from the front.

Internal angles or "bird's-mouth," and external angles or squint quoins, are measured at per foot run, and described as fair or rough, as the case may be.

Chimney Shafts and Flues.

Chimneys and flues are measured as solid.

The opening only for the fireplace being deducted from the top of the hearth to the under side of the chimney bar.

Take fire-bricks and fire-lumps extra.

Number the coring of the flues.

Take chimney bars according to size, and 24 inches longer than the clear opening, unless otherwise specified. They are afterwards inserted in the smith's bill by weight.

Ovens and Coppers.

At per foot cube.

Brickwork in ovens and coppers is measured solid, some surveyors deducting the ash-holes only.

Fire bricks and fire lumps are taken extra.

Arches and Vaults.

At per rod reduced.

Take the length by the mean girth and thickness, and describe how they are to be executed, whether straight, askew, spandril on plan, fluing, or otherwise.

In groined arches, when the groins spring from four piers or angles, the parts groined are to be kept separate and the run of cut and rubbed groin point taken in addition ; in other cases take the cut and rubbed groin point only. In all cases the rough cutting at the intersection of the arches should be taken.

Some surveyors, however, make no distinction for groined arches, beyond taking the run of groin point and rough cutting.

Measure the soffits of all arches and vaults for centering ; those for groined, fluing, and similar arches to be kept separate. Take groin points, cuttings, and extra ribs where required.

Take raking out and pointing to soffits ; an operation which cannot be performed until after the centres are removed.

Take the rough cuttings for skewbacks and the other cuttings when the arches are not straight.

The faces of skew arches require to be fair cut.

Walls built over and under the arches require to be rough cut to fit the curvature.

Trimmer arches are to be taken at per foot superficial, stating the thickness.

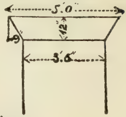
Arches Gauged or Fair Axed.

At per foot superficial.

Gauged arches over door or window heads are to be taken as extra to the ordinary brickwork, deducting for the facing only.

Measure the width of the opening between the reveals, and add the projection of one skewback; this length by the height will give the face, to which add the soffit, for example:

4	3	Extra to gauged arches
1	0	and ddt. external facing.
3	6	
0	4½	add gauged soffit.



3	6	opening
0	9	skewback
4	3	

When the arches are cambered or curved they are measured in the same manner, the net face and soffit being taken.

Take rough cutting to skewbacks as before.

Some surveyors in addition take the length of the joint on the face as "Run of cut skew in facing," and also over arches that are curved on the extrados.

Take turning pieces for the straight or cambered arches at per foot run, stating the width of soffit, whether 4½ inches or 9 inches.

Take centres for the other arches at per foot superficial.

Rendering.

At per yard superficial.

Rendering by the bricklayer is charged as from the trowel, stating the thickness and proportions of which the mortar or cement is composed.

Pointing.

At per foot superficial.

Describe as "*Raking out joints and pointing with coal ash mortar, or cement,*" or "Tuck pointing," as the case may be.

Raking out joints of brickwork or masonry, and pointing to lead flashings, are to be taken at per foot run.

Bricknogging.

At per yard superficial.

Take the length by the height, and deduct all the openings, but not the timbers.

Brick or Tile Paving.

At per yard superficial.

Describe the bricks or tiles used, the thickness of the tiles, and whether the bricks are laid flat or on edge, in mortar or in sand.

Brick on Edge Coping.

At per foot superficial.

State if in cement or in mortar. Sometimes it is taken by the foot run, and when so, state if on 1 or 1½ brick wall, or as the case may be.

Roof Tiling.

At per square of 100 superficial feet.

In Plain Tiling—

Allow for the eaves 4 inches extra.
" dripping ditto 6 inches extra.
" all cuttings, hips, &c., 3 inches extra.
" valleys 12 inches extra.

In Pantiling—

Take the length of the hip rafter by 12 inches for cutting and waste.

Take the run of "Hips and Ridges."

Take the run of mortar or cement filleting, also the plain tile heading.

In both cases number the hip hooks and T nails, &c., and the painting in oil.

Give the gauge of the tiles, the quantity and description of the laths and nails used, state if laid dry, or pointed outside or inside with mortar.

Drains.

At per foot run.

Describe and state if in mortar or cement. If barrel drains, state the number of half bricks in the thickness.

State if digging is included.

Moulds, templates, and centres for drains are charged extra.

In pipe drains, all bends and junctions are taken extra.

The total length for pipes should be some multiple of that for a single pipe.

When pipes have to be cut, they should be numbered and described as "Extra to cut length."

Cesspools.

It is customary to number small cesspools. State if square, or circular, also give the depth, width, or diameter, and if rendered on the inside with cement.

Large cesspits should be measured as ordinary brickwork.

Making good pipes or other drains to cesspools is charged extra.

Miscellaneous.

Take fascias, beads and quirks, rounded angles, dentil or plain cornices, cutting and pinning landings, &c., at per foot run.

Number the mitres and stopped ends to all splays, rounded angles, &c. Also number the bedding and pointing to door and window frames; ends of timbers, stone steps, &c., cut and pinned. Ventilators and air-bricks, built into walls, forming and rendering the apertures for same. Chimney-pots and fixing. Ranges and stoves fixed. Chimney-pieces fixed. Chimney opening rendered and blackened.

The term "labour only" is exclusive of scaffolding, but includes its erection.

"Labour and mortar" includes scaffolding and other materials except bricks.

WALLER AND MASONS' WORK.

In districts where stone abounds and forms the principal material for building, ordinary walls are commonly built of rubble stone, and paid for by the cubic yard, or some other local standard, according to the quality of the work—as "coursed" or "uncoursed" "in foundations," "walling," &c. A considerable quantity of workmanship is frequently applied to this kind of masonry, so that sometimes it becomes little inferior, on the face, to dressed block stone.

The face work is measured separately, and paid for by the foot superficial, as "scabbled," "hammered," "axed," &c., including any squaring to the beds and joints of the facing stone.

Quoins of selected stones are described and charged at per foot in height, but superior quoins are taken as block stone, and other dressings are taken in a similar manner.

Block stone is charged in the quarries at per cubic foot, or per ton, and the price varies as follows, viz.:—

1. When one dimension is fixed as the height of a course of ashlar, and the other two dimensions are left, more or less, to the option of the quarryman.
2. When two dimensions are fixed as the height and width of a coping, and the third dimension is left optional.
3. When all the dimensions of a stone are fixed.

The value of a block of stone will be reduced if the back be not scabbled square, but left rough to tail in with a rubble wall or otherwise; and it will be still more reduced in value if, in addition to the back, some portion of the sides or joints also be left rough.

WALLING of block stone is charged at per cubic foot according to description, as ashlar prepared and set, including all beds and joints, but the face is charged extra at per foot superficial, as "drafted and picked," "tooled," "rubbed," &c.

COPINGS, ARCH STONES, &c., are charged at per cubic foot for the rough stone and setting, the dimensions of each stone being taken as that of the smallest rectangular block from which it could be prepared, and the dressing is measured on the surfaces of the prepared block, and charged as "beds and joints," "sunk joints," "plain face," "sunk face," &c.; or, more commonly, an addition is made to the cubic price of the stone for plain beds and joints, and only the face work and sunk joints charged as superficial work.

In London, in consequence of the difficulty and expense of carriage, very little stone, comparatively, is used, and that little is chiefly in small quantities at a time, and in small scantlings.

The building stone used in London is chiefly obtained from the island of Portland, or from the neighbourhood of Bath. Both of these descriptions of stone are quarried from the same geological formation, and they are very easily wrought. Portland stone is brought to the London market in roughly-hewn rectangular blocks, which are sold by the ton of 16

cubic feet, 1 inch in each dimension of the block being allowed for irregularities and waste.

The London mason cuts the block into scantlings by means of the saw, and his work is measured as follows :—

MATERIAL.

Per foot cube.

Take the size of the stone as it comes to the banker, and describe as "Cube stone, including hoisting and setting."

All stones above 6 feet long to be described as scantling lengths, and each size kept separate.

The height to be stated when the work is more than 40 feet from the ground.

All stones under 3 inches in thickness are to be measured by the foot superficial.

LABOUR IN GENERAL.

Per foot superficial.

It is the practice with most surveyors to take only one bed and one joint to each stone ; it is better, however, to measure all if worked, and to state that such has been done.

One joint only to be allowed to every 3 feet in length when the work is continuous, as in strings, copings, &c.

Take half sawing to all sawn faces, on which no other labour has been taken.

Take plain work rubbed (which includes sawing) to all faces and returned ends unless otherwise worked.

Girth the sunk work, moulded work, circular plain, and circular moulded work as it appears, and take beds or half sawing, as the case may be, on the original surfaces extra.

NOTE.—The tendeney of the modern practice is to assume that the finished work includes all preparatory labour.

Take splayed and fair edges under 6 inches wide, back joint, throating, grooving, sunk rebates, mitres to sinkings, chamfers, reeds, flutings, haunches, joggle and iron or copper tongued joints, cutting and pinning to landings, &c., by the foot run.

Number fair ends to steps, pipe holes, cramps, plugs, dowels, mortise holes for doorposts, rounded corners, notchings, letting in coal plates, air traps, sink stones, cutting and pinning ends of steps, stopped and bevel ends to sinkings, mitres to mouldings, external and internal (according to girth), returned and mitred ends to copings, neckings to chimney pieces, &c.

Definitions of Terms for the Labour on Stone.

Plain Work—is the even surface produced without sinking more than necessary to remove the mere irregularities of the stone, and is divided into *plain face*, which is dressed, and *plain bed*, or *joint*, in which the stone is merely taken out of winding.

Sunk Work—is the cutting or chiselling below the plain surface, as in rebating, or the weatherings of string courses, copings, and cornices.

Circular Work—is the labour required to form convex surfaces, as to the shafts of columns.

Circular Sunk Work—is the labour required to form concave surfaces, as for the soffit of arch stones, or the hollow side of circular curbs.

Circular Circular Work—is that required to form a sphere or a niche head.

Moulded Work, Straight—is that to cornices, &c.

Moulded Work, Circular—is that to the necking or capitals of columns.

Work in Portland and other Soft Stones.

Plain Solid Steps.

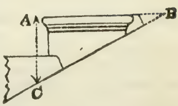
Per foot run.

Measure the length, and describe the width and depth. State if tooled on tread and riser and back-jointed, or tooled all round, as the case may be.

Take fair or rounded ends, or cutting and pinning to walls, &c., extra.

When steps are bedded on brickwork or stonework it should be stated.

Spandril Steps.



For the Cubic Quantity of the stone. Take the length by the width, measured from the nose of the tread at A to the end of the acute angle at B, and by half the height of the riser, measured from the top of the tread at A to C, where the vertical line intersects the soffit.

Take Plain Face (rubbed) to tread and soffit as seen when worked.

Take the girth of the rebate by the length, as Sunk Work.

Take the length of the nosing, including the returned end, by the girth as Moulded Work, and the face of the riser from the nosing to the rebate as Sunk Work.

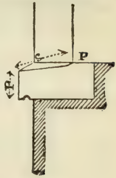
Take half sawing to the original surfaces of the sunk and moulded work.

Number the mitres to moulding (state the girth)—
Returned end to moulding (1).
Step cut and pinned in wall (1).
Holes sunk for balusters (2).

NOTE.—The under side of spandril winders to be taken as CIRCULAR PLAIN WORK WREATHED.

WINDOW SILLS.

These in Portland stone are usually taken by the foot run, with extras for throating and ends, but it is desirable here to show how they would be measured, viz:

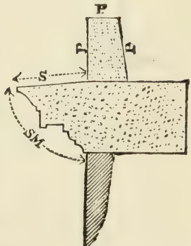


Take the extreme dimensions for the CUBIC QUANTITY of stone.
PLAIN FACE, P to the top, front, ends, and under side of projection.
The girth of the top S, as SUNK WORK, and the original surface as PLAIN BED.
Sawn sides and ends as HALF SAWING, when no other labour is taken.
Run of THROAT and describe as stopped. Also GROOVE for metal tongue.
No. of STOPPINGS and MITRES, describing their length.

"Making good to window sills" should be taken if the stone is deducted from the brickwork.

CORNICES, &c.

Take for the Cornice—



The extreme dimensions for the CUBIC QUANTITY of stone.
BEDS and JOINTS for the top, bottom, and ends.
SUNK FACE to the top, measured from the blocking course to the outer edge.
MOULDED WORK from the edge of the sunk work over the face and soffit to the wall.
ROUGH SUNK FACE is usually taken in addition to moulded or other sunk work if more than 3 inches below the original face of the stone.
HALF SAWING to the front and back (if sawn).

Take for the blocking—

The length and height by the mean thickness, *plus* ¼ inch for waste in sawing, as the dimension for the quantity of stone.

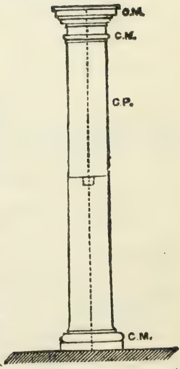
Beds and Joints.

Plain Face to front, top, and back.

Run of Groove for plug.

Number of plugs and running with lead.

Columns.



Shaft exclusive of base or capital—

Take for the cube of material the extreme dimensions of each stone as if square.

Take for the labour.

Plain Joints where jointed.

Plain Bed on two sides.

Circular Plain Face to girth of shaft.

Circular Moulded Work to necking.

Number of mortise holes and dowels.

Capital and base—

Take extreme dimensions as before for the material.

Plain Bed to top, bottom, and sides.

Plain Face rubbed to fillet on top of capital and to plinth.

Circular Moulded Work. Average horizontal girth by vertical girth of moulding.

Rough Sunk Face under the moulded work if the sinking is more than 3 inches deep.

Mortises and Dowels as last.

Note.—The face labour on columns is usually kept separate.

Bath and Yorkshire stone are measured in the same way as Portland stone; but for ordinary work Yorkshire steps, curbs, &c., may be obtained in the London market ready dressed from the quarry, and they are usually taken at per foot run and charged at lower rates than if they were prepared from the block stone in London.

Yorkshire landings (i.e. stone over 3 inches thick or 15 feet super.) and pavings are measured by the foot superficial, stating the thickness, and if tooled on one or both faces, quarry worked, self-faced, or otherwise; also if the tooled work is rubbed.

Landings over 6 feet in length should be kept separate.

Take the tooled edges to the landings, when over 6 inches wide, by the foot superficial; and when under 6 inches, by the foot run, according to width. Take cuttings and pinning, joggle joints, &c., to landings, the same as for Portland stone. Take coped edge to paving when a close-fitting joint is required.

To GRANITE and other stones not usually sawn, two beds and two joints are taken where only one is frequently taken to Portland or other sawn stones. The labour is usually described as "Scabbled," "Rough picked," "Fine picked," "Single axed," and "Fine axed."

In granite all beds and joints are described as "Plain picked," or "Plain axed beds and joints," and the stones are measured at their largest dimensions for the cubic contents, as they cannot be sawn one out of another.

MEASUREMENT OF GOTHIC AND OTHER MASONRY AS APPLIED UNDER THE CONTRACT FOR THE ERECTION OF THE HOUSES OF PARLIAMENT.

Cube Stone.—If square to be measured the net size when worked, but when the stones are not of a square form to be measured to the size of a square stone of the least extent required. Where the stones are of scantling lengths of 6 feet and upwards, they are to be measured separately from the ordinary cube stone.

Drafted Backs.—The backs of the stones where drafted to be measured according to the surface actually shown.

Plain and Sunk Beds.—One plain bed only to be taken for each stone, except to mullions of windows, for which two beds are to be taken to each stone. Ordinary arch stones to be considered as having one plain bed and one sunk bed.

Plain and Sunk Joints.—Not more than one plain joint to be taken for each stone, having one or more plain joints. All sunk joints to be taken as they occur.

Chiselled or Rubbed Faces.—To be measured to the size actually shown on the external surface.

Rough Sunk.—To be taken when a large quantity of stone has to be removed, as in stop mouldings to sills, window heads, and other similar work.

Sunk, Chiselled, or Rubbed Faces.—To be measured on the surface actually worked, adding the depth of the sinking.

Stopped Sinking.—To be measured in such situations as do not permit the work to be carried straight through the stone, as in sills of windows, and other similar work.

Preparatory Labour or Plain Face as Bed.—To be taken wherever it is necessary to produce a face for the purpose of setting out under work, as in tracery heads, and other similar works. This is also intended to apply to mullions of windows, one side and one edge of which are to be taken as plain bed.

Sunk, Chiselled, or Rubbed Face in short lengths to hexagonal Canopies. To be measured as they occur, including arrises.

Mouldings.—To be girthed the surface actually shown; the top bed, if weathered, only to be measured as sunk face.

Moulding to Panelling.—To be girthed, including the back of the panels.

Circular Face to soffit of Cusps.—To be measured the whole thickness of he stone from back to front.

Circular Face to soffit of Cusps in Panelling.—To be measured from the external face of the stone to the face of the panelling.

Sunk Faces to Tracery Heads of Panelling.—To be measured net on the face, adding the depth of the sinking from the external face.

Sunk Face in margins for Eyes.—To be measured the extreme length and width.

Circular Sunk to related soffit of Cusps—To be measured from the external surface, adding the depth of the rebate.

Mouldings in Tracery.—The extreme lengths of the straight mouldings in the tracery of the window heads to be measured through the mitres and junctions with other mouldings.

Throat.—To be measured per foot run.

Groove for Cement.—Ditto.

Groove for Metal ashes.—Ditto.

Rebate not exceeding three inches girth.—To be measured per foot run.

Mitres to Sinkings.—To be numbered according to width.

Mitres and Returns to Sinkings.—To be numbered according to the width of the sinking and length of the return.

Mitres to Mouldings.—To be numbered according to the girth of the moulding.

Mitres to long intersections of Cusped and other Mouldings.—To be numbered according to the girth of the moulding.

Mitres and Returns to Mouldings.—To be numbered according to girth of moulding and length of return.

Stopped ends of Mouldings.—To be numbered according to girth of moulding.

Stopped ends of Mouldings on splayed Sills and Sills of Panels.—To be numbered according to the girth of the moulding and extreme length from top of sill to point of intersection.

Rough Sinkings for Cusped Window Heads and similar Sinkings.—To be numbered, taking the average area of the sinking and the full thickness of the stone.

Holes punched.—To be numbered according to their area and depth.

Sinkings to form Shingles.—To be numbered as they occur, according to length, width, and depth of sinking.

Notchings to form Embrasures.—To be numbered according to their height, width, and depth of sinking.

Water Joints.—To be numbered according to their projection.

Mitres to soffits of Cusps in Tracery Heads of Windows.—To be numbered according to their length, and taken the full thickness of the stone.

Ditto in small Tracery Heads of Panelling.—To be numbered according to their length. Measured from external face of stone to back of panelling.

Points to Cusps in Tracery Heads of Windows.—To be numbered according to their length, and measured the whole thickness between the sunk faces.

Ditto in small Tracery Heads of Panelling.—To be numbered according to their depth from sunk face to back of panelling.

Sunk and moulded Œilets, each with one mitre and two long intersections.—To be numbered according to extreme size.

Small Sunk Eyes—To be numbered.

Cramps out of Saw Plate.—To be numbered according to length.

Cast-iron Cramps.—To be numbered according to length and thickness.

Plugs.—To be numbered according to length and size.

Small Copper Joggles and Mortises.—To be numbered.

Stone Joggles and Mortises.—To be numbered.

Joggles to Vertical Joints with Pebbles in Cement.—To be numbered according to size.

Pavings and Landings.—To be measured per foot superficial.

Perforations to Landings.—To be numbered according to size and the thickness of stone.

SLATER AND SLATE MASON.

Measure slating to roofs by the square of 100 feet superficial; give the size and usual denomination of the slates, their gauge, and the description of nails used. State if the slating is circular or upright, but make no allowance in the measurement, as the additional labour should be paid for in price.

The dimensions for slating are usually taken along the eaves in front and rear, to the extreme ends, by the width from the eaves to the ridge, whether the roof is hipped or gabled.

Deduct all openings, such as chimney shafts, traps, skylights, or dormers, but allow the run of edge around the same by 6 inches for cutting and waste.

Add for all raking edges and irregular angles the length by 6 inches, and for hips and valleys the length by 6 inches on each side; or take a running dimension for cutting and waste.

It is usual to allow for the under course to eaves and gutters, the length by the gauge of the bottom course; on the supposition that an extra length of slate is used, which is not always the case.

Run all filleting, and state if in mortar or cement.

Slate Masons' Work is usually measured by the foot superficial.

For Slate Shelves, take the length by the extreme width, give the thickness, state if rubbed or planed on one or both sides, and give the actual size if over 6 feet in length or 3 feet in width.

Take sawn, rubbed, filed, bevelled, or rounded edges, fillets, rebated, or grooved and tongued joints, stating if in red-lead or putty, all at per foot run. Take cutting and pinning to walls at per foot run.

Number holes (according to diameter), notches, and rounded corners, stating the thickness of the slate, also the kind of screws used, and the holes for the same.

Slate Skirtings, Rolls, and Covers to hips and ridges are taken at per foot run, according to thickness and width; state if bedded in putty or red-lead. Number the screws and drilling the holes for the same.

Slate Cisterns are usually numbered and described according to capacity and manner of putting together. Holes for pipes and fixing are taken extra.

CARPENTERS' WORK.

The carpenter is employed in the construction of roofs, floors, partitions, and in all those operations of building where timber is used in large scantlings. His work is generally charged by the foot cube, and the full quantity of timber used, such as tenons to framing, the bevelled ends to rafters, laps, scarfs, &c., are to be included in the measurement; deduction being made only when the part cut out is available for other work: and even then it is customary to make a liberal allowance for waste in converting to use.

In large timbers it is usual to allow for a scarf in every 20 feet of length.

The labour on timber is generally classified as "Fixed only," "Framed," or "Framed and fixed."

Timber fixed includes the labour in nailing, spiking, halving, dovetailing, or notching

Timber framed includes mortising and tenoning.

Measure all timbers under 3 inches square at per *foot run*, describing what they are; above 3 inches square they are measured at per *foot cube*

Timber over 25 feet in length or 15 inches in depth should be kept separate.

Bond Timber, &c.

Take bond timbers, wall plates, pole plates, templates, and lintels, under this head, at per foot cube; and add for laps, dovetails and scarfings in the measurement.

Allow for laps, 6 inches to every 16 feet for fir plates, and to every 12 feet for oak.

Deduct half the length of bond timbers to door or window openings if carried through.

Wood Bricks.

Number the wood bricks; give the size, and state if cut on the splay. Six are usually taken to each door and window, for the purpose of fixing the jamb linings. If the windows are more than the ordinary height, allow eight wood bricks to each.

Floors (Naked).

Take all joists and sleepers which have not been actually framed at per foot cube, as "Fixed" only.

Keep ground joists and sleepers distinct from those to upper floors.

Girders, binders, trimmers, and trimming joists are to be taken as framed.

Girders sawn down the middle, reversed and bolted, or trussed, are to be kept separate.

Take the oak trusses at per foot run. Give the scantling, and state if in unusual lengths. Letting in screw bolts, plates, &c., are to be numbered as extras.

Take strutting between the joists by the foot run; give the scantling, and state if herring-bone or otherwise.

Roofs.

Take king posts, queen posts, principal rafters, and tie beams at per foot cube, as "Framed in trusses."

Deduct one shoulder from the king posts and one half from the queen posts. Allow in the length for each tenon.

Note.—In practice surveyors seldom make any deduction from the king or queen posts.

Take common rafters, purlins, diagonal ties, dragging pieces, and gutter plates, except where actually framed, at per foot cube, as "Fixed in rafters," &c.

Add to all ironwork extra for fixing.

Take ridge, hips, and valley pieces by the foot superficial, allowing for scarfs 1 in every 15 feet, and state if framed or otherwise. Measure the cuttings and waste by the foot run.

Take the slate boarding or battening by the square of 100 feet superficial, give the thickness, and state at what distance the battens are apart and their width.

Boarding to flats should include firrings.

Run all cuttings and bevelled edges.

Take tilting fillets to slate boarding by the foot run.

Take feather-edged eaves boarding to slate battening by the foot run, and state the width and thickness.

Hip and ridge rolls are measured by the foot run, allowing for laps. Give the diameter, and state if spiked or otherwise.

Number Cut Ends to feet of rafters.

Gutters, Boards and Bearers.

Measure the length of the gutter by the average width, and include half the lear boards (when the roofs are battened), give the thickness of the gutter boards, the size of the bearers, distance apart, and state if framed.

Note.—Some surveyors measure lear boards separately.

Number the drips and cesspools.

When the roofs are slate boarded a fillet is used to tilt slates instead of the lear boards, which should be taken by the foot run as to eaves boarding, &c.

Trap Doors in Roof, &c.

Deduct the rafters for the opening, and add the trimmers, take the trimming rafters, &c., as framed, or allow for the extra labour in trimming the rafters.

Take the linings to the opening and the rim by the foot run, give the width and thickness of each, and state if wrought, splayed, or dovetailed at the angles.

Measure the trap door by the foot superficial according to thickness, and describe as "Wrought ledged, and filleted," or as the case may be.

Take to each door a handle and bolts, according to description.

Quarter Partitions.

Take the head, sills, braces, quarters, door heads, &c., at per foot cube, and describe as "Framed in trussed partitions," or otherwise, as the case may be.

Deduct for doorways, &c.

NOTE.—The quarters, if tenoned into the head and sill and spiked to the braces, are to be considered as framed, but not otherwise.

Collect the hogging pieces at per foot run, stating the width and thickness.

Ironwork and fixing to be taken extra.

CEILING JOISTS.

Measure ceiling joists the same as flooring joists, by the foot cube.

Take the trimming as described for the roof.

WALL BATTENING.

Take wall battening at per square of 100 feet superficial.

Collect the round of the walls by the height, give the thickness, width, and distance apart, also state if plugged to the wall or otherwise.

Deduct all openings.

ROUGH BOARDING.

Take rough boarding at per square of 100 feet superficial. Measure the length by the width, and where irregular take the average, allowing extra for all cutting and waste at per foot run. Give the thickness of the boarding, and state if edges shot, ploughed and tongued, or otherwise.

Some surveyors take the length of all cuttings by 3 inches, which they add to the boarding for labour and waste.

Keep boarding to ceilings or walls separate, as they require more labour. Where laid to current, take firrings by the foot superficial, stating the average size and distance apart.

SOUND BOARDING.

Take sound boarding at per square of 100 feet superficial. Measure the length by the width, including the joists, and state if on single or double fillets.

Some surveyors, however, only take the width between the joists; therefore, whichever way it is taken should be stated, so as to regulate the price.

Bracketing, &c.

Bracketing is measured by the foot superficial.

When for cornices, take for the length the round of the room, deducting one projection of the cornice each way by the girth. State the thickness of deal used, and if plugged to wall, &c.

The angular brackets are taken extra and numbered.

Take bracketing to circular and groined ceilings the length by the girth, and state if the diameters are small.

Cradling for entablatures is taken at per foot superficial according to thickness.

In all cases state if done in small quantities.

Wrought, Framed, and Rough Timbers in General.

Take wrought timber under 3 inches square at per foot run, according to the scantling.

When timbers are large and partially wrought, they are usually taken as if rough, and the labour of planing taken extra at per foot superficial, and the rebating, beading, &c., by the foot run, according to description.

Circular timbers are measured as they appear, adding the laps, scarfs, &c.; the labour and waste being charged in the price.

State if a flat or quick sweep, a rise of less than half an inch on a chord line of one foot being considered a flat sweep.

When the curve is other than circular it should be stated.

State when large timbers (20 feet cube) are hoisted over 30 feet, and also when of unusual length.

Centering.

(See Bricklayer).

Centering to vaults is charged at per square of 100 feet superficial, and state how supported, centres for groined arches to be kept separate, and take run of groin point, extra also for splayed cutting.

Centering to trimmer arches, gauged and other arches over openings, when the soffit is more than 9 inches wide, is taken at per foot superficial; if under 9 inches in width, by the foot run, and describe the nature of the curve.

Take feather-edged pitching pieces to trimmers at per foot run.

Notching for key stone, if required, should be numbered.

Fences.

Wood fencing is generally measured by the lineal rod of $16\frac{1}{2}$ feet, and charged according to description; but fancy fencing must be taken in detail.

JOINERS' WORK.

In the joiner's work is included the fittings and decoration in wood to buildings, and his labour forms a much larger proportion to the value of the material on which he is employed than that of the carpenter, consequently the mode of measuring and valuing is different. The carpenter's work, as we have before stated, is for the most part measured by the cubic foot; the labour of the joiner being spread over the surface, such a mode, under the varying circumstances of size and application, would not give the proper value, therefore the *superficial foot*, or square of 100 feet, is adopted as the rule in estimating the value; exception only being made in very small or difficult works, which are usually numbered.

The terms "Fixed" and "Framed" admit of the same definition as in the carpenter's trade, but a distinction is made in the superficial measurement of the framed work by including the length of the tenons in the dimensions for the carpenter, and omitting them for the joiner.

By the term "Flat sweep" in curved work is to be understood a rise of half an inch on a chord line one foot long.

"Quick sweep" is when the rise exceeds half an inch.

Flooring.

Per square of 100 feet superficial.

Take the length by the width, and add the pieces filled in to windows, recesses, &c.

If the room is of an irregular shape, take the average size.

The flooring in door openings, &c., should be taken and described as "including bearers."

Take the length of the raking edges and describe as

"Cutting and waste," or measure the length by a width of 3 inches, and add to the flooring, circular cutting to be described in a similar manner.

Scribing the edge should be taken when the floor butts against stone or brickwork, and no skirting to cover the edge.

Deduct the slabs, chimney breasts, and other projections.

Give the thickness, state the kind of timber, width of boards, and mode of laying.

Extras.—Take the glued and mitred border to slabs by the foot run.

Skirtings.

Per foot run.

Take the round of the room, and add for the passings at the angles.

Give the thickness and width, state if moulded or otherwise, and if backings are included, and if plugged to wall keep separate.

Extras.—The number of tongued or mitred angles, housings to architraves, &c., and fair returned ends.

Narrow Grounds.

Per foot run.

Take the length as described for the skirting.

Give the thickness and width, state if chamfered, plugged to wall, or otherwise.

Grounds over 3 inches wide to be measured by the foot super.

Sashes and Skylights (Fixed).

Per foot superficial.

Take the width by the height from outside to outside, and if two sashes in height, allow 1 inch for the meeting rail.

Give the thickness, and state if the bars are square, chamfered, or moulded, and put together with white lead.

Extras.—Take the beads, stops, and linings by the foot run, according to the thickness, width, and labour upon them; also labour to throat.

Sashes and Frames (Cased).

Per foot superficial.

The usual mode for ordinary frames is to take the width between the pulley stiles, adding 4 inches on each side for the frame. Take the height from the top of the sill to the under side of the head, and add 4 inches for the head and 3 inches for the sill.

Note.—To obtain the size of the frame, some surveyors add 9 inches to the net width of the external opening in the wall, and 3 inches to the height between the top of the stone sill and the soffit of the arch.

State if the sill is of oak, single or double sunk, weathered or throated, give the thickness of the pulley stiles, head, and linings, the size of the sash beads, thickness of the sashes and sash bars, and if moulded or otherwise; the mode of hanging the sashes, the quality of the lines, pulleys, and weights.

If the sashes have marginal lights, state whether they are perpendicular, or perpendicular and horizontal.

Extras.—Take the run of metal tongue and groove in oak sill, also bedding sill in white lead. Number the moulded horns (if any), the sash fasteners, sash lifts, &c., according to description.

It is usual to number any sash and frame under 12 feet super., stating the extreme height and width.

Sashes and Frames, Circular on Plan.

Per foot superficial.

Take the height by the girth, with the additions for the frame and sill, as pointed out for straight sashes and frames.

Describe the same as for straight sashes and frames, but circular on plan: state if quick sweep or flat sweep.

Extras.—The same as for straight.

Sashes and Frames with Circular Heads.

Per foot superficial.

Take the lower part to the springing, the same as for square sashes and frames.

Take the circular head separately, the height by the width.

Describe as "Circular heads to sashes, and frames measured square."

Extras.—The same as for square sashes and frames.

French Casements.

The sashes are measured net, and described as for ordinary sashes at per foot superficial, adding ½ inch to the width for the rebate in folding casements.

The frames and sills are measured solid, the same as for door frames; if with transome it should be taken at per foot run, and described according to the labour on it.

Extras.—Run of rebated edge to lower rail of sashes.
Do. of water bar.
Number and description of hinges of Espagnolette bolts or other fastenings, stay hooks, &c.

Window Linings and Window Boards.

Per foot superficial.

Take the length by the width in each case, allowing for window board 5 inches more than the greatest width of the opening, or 1 inch beyond the architrave, if one is stopped on it.

Give the thickness of the linings, and state if rebated to frames, grooved, beaded, tongued at angles or rounded.

For the window boards and bearers state the thickness, also if tongued to the sill and rounded or moulded on the edge.

Linings or window boards under 6 inches wide to be taken at *per foot run.*

Extras.—The labour to grooves at per foot run.

Number of notched and returned rounded or moulded ends to window boards.

Framed Grounds and Architraves.

Per foot superficial.

Take the round on the outside edge by the width for the ground.

Give the thickness, and state if grooved, splayed, beaded, mitred, or back rebated.

Grounds under 3 inches wide to be measured at *per foot run.*

Extras.—The mouldings round the grounds to be taken at per foot run.

Number the mitres to the mouldings and take extra to splayed or moulded plinths.

Moulded architraves are measured along the outer edge of the moulding, stating the girth, and charged by the foot run.

Shutters and Backflats.

Per foot superficial.

Take, for the dimensions of the shutters, the height by the width, including the rebates.

Take the backflaps in the same manner, but keep them separate.

Give the thickness of the shutters, the number of panels, and state if hung in one or two heights, also if square framed, flush panel, moulded, or otherwise.

In like manner describe the backflaps.

Extras.—Hinges to the shutters and backflaps according to size.

Shutter bars according to length and description.

Shutter knobs according to description.

Window Backs, Elbows, and Soffits.

Per foot superficial.

Take the length of the back and elbows, including the passings, by the height from the floor to the under side of the beaded capping.

Take the soffit by its extreme length and width.

Give the thickness and number of panels, also state if splayed plain, keyed, square, flush panel, or moulded.

Extras.—Take the beaded capping to window back at per foot run, stating width, thickness, if tongued, or with moulding tongued under.

Number the elbow caps and freeing bead according to size and description.

Back Linings.

Per foot superficial.

To the height taken for the shutters add 2 inches for that of the back lining, by the width.

Give the thickness, state if plain or panelled, the number of panels in height, and if square, flush, or moulded, also if splayed.

Boxings.

Per foot superficial.

Take the height, including the framings, by the width.

Give the thickness, and state if wrought, framed, rebated, beaded, or splayed; if all, they are termed "Proper boxings." If flush with wall they are usually called "Boxing grounds."

Lifting Shutters.

Per foot superficial.

Take the net height by the width when up, adding the passings when hung in more than one height.

State the thickness, number of panels, the mode of framing, &c., and in how many heights they are hung; give the size of the pulley pieces and beads, the quality of the lines, weights, and pulleys.

Take the cased frame, which is similar to that for sashes, at per foot run.

Extras.—Take the run of groove for the beads.

Take the run of flap to cover the shutters when down, according to thickness and description.

The grounds, &c., to be taken as for window fronts.

Take the fastenings, and flush rings to the shutters, and hinges to the flap.

Outside Shutters.

Per foot superficial.

Take the height by the width, including the rebates (if folding).

State the thickness, number of panels to each fold, the mode of framing, and give a description of the mouldings.

Extras.—Take the hanging piece at per foot run, according to size.

Hinges, rings, and turnbuckles, according to size and description.

Door Frames, Solid.

Per foot run.

Take the round of the frame, including the tenons into the head. Add 6 inches for the horns, if any, and 2 inches for each stub to the sill.

Take the oak sill separately, the length by the width and thickness.

State the size, and if wrought, framed, rebated, and beaded, double beaded, or otherwise. State if the oak sill is wrought, framed, and weathered.

Extras.—Should the sill be of stone instead of wood, take iron shoes (or otherwise), and fixing to the feet of the door frame.

When the head is circular, measure the straight part as for square-headed frames to 3 inches above the springing, and take the circular part from the springing at per foot run, stating the size and workmanship; also take the number of heading joints, oak keys and wedges, &c.

Gates, Framed.

Per foot superficial.

Take the height by the width, adding one rebate (if hung folding).

Give the thickness of the gate, and state how framed and hung.

Extras.—Take the run of capping, according to description.

Number the wicket extra for forming, fitting, and hanging.

Take hinges, bolts, locks, latches, swing bar, or other fastenings, and iron lining to sill.

Stay hooks and eyes, and fixing.

Doors Ledged.

Per foot superficial.

Take the height by the width, including the rebates, if hung folding.

Give the thickness of the door and size of the ledges, and state whether wrought, ploughed, tongued, and beaded; if all, they are termed "Proper ledged doors"; also state if braced.

Extras.—Take the hinges, locks, latches, and bolts, according to the usual description.

Doors Framed or Panelled.

Per foot superficial.

Take the height by the width, and, if folding, include the rebates.

Give the thickness of the door, and the number of panels (per *set* if folding doors), state if bead butt, bead flush, chamfered or moulded, as the case may be, or if the upper panels be open for glass, in which case, if heavy glass is used, take beads fixed with brass screws and cups.

Take a run of splayed edge on top rail to doors hung with rising butts.

Extras.—Hinges, locks, bolts, knobs, &c.

Note.—Circular and Gothic heads are to be taken separately, and measured square from the springing. Surveyors usually take the whole door, and describe it as with "circular head measured square."

Jamb Linings.

Per foot superficial.

The length of the jamb linings is usually collected by adding twice the height of the sides to the width of the door, *plus* four times the thickness of the jamb linings.

Give the thickness, state if tongued to architraves or grounds, if single or double rebated, if beaded on both edges, and if framed in panels (with the description and number).

Extras.—The number of dovetailed or other backings to receive the hinges, bolts, and locks.

Door Grounds Framed.

Per foot superficial.

Take the length by the width.

To find the length, take that found for the door jambs, and add for the passings at the angles four times the width of the ground.

Give the thickness, and describe according to the amount of labour.

Extras.—Take the architrave or the mouldings round the grounds, as described for window fronts.

Framed Partitions.

Per foot superficial.

Take the length by the height measured over all (deducting door openings), give the thickness, and describe the mode of framing as for doors, &c.

Measure doors at per foot super., and describe as before.

The fillet round the door opening is usually measured extra at per foot run, and described as chamfered or moulded, as the case may be.

Note.—Spandril framing (such as that under staircases) should be measured net, and treated in a similar manner to partitions as regards doors, &c.

If the panels are filled in with glass, the latter should be taken separately.

Staircases (Flyers).

Take the extreme length of the tread, including the housings into the strings, by the collected widths and heights of the treads and risers, measured from the front of the riser to the nose of the tread for one, and from tread to tread for the other, as in the sketch.

Give the thickness of the treads and risers, with the number and sizes of the carriages (if any).

State if the steps are wrought, glued, or blocked, if with

moulded or rounded nosing, if cut and mitred to string, at one or both ends, as the case may be.

Extras.—Number the curtail end to bottom step, according to description.

Take grooving and tonguing by the foot run ; also take the run of nosing on the floor to form the upper steps.

Take housings to the steps and risers.

Sinking for balusters.

Number of returned moulded nosings.

Number of cut or moulded brackets on string, according to description.

Take all fascias, apron linings, &c., by the foot superficial, according to description.

Staircases (Winders).

Per foot superficial.

Take the whole of the space occupied by the winders. Collect the lengths of the risers by the height, *plus* 1 inch for each nosing on the winders.

State the thickness, &c., as pointed out for the flyers.

Extras.—Take the grooving and tonguing by the foot run.

Number the housings to the winders, and keep them separate from those of the flyers; also the returned circular nosings to the steps, and the number of circular cut brackets where required.

String Boards.

Per foot superficial.

Take the extreme length, including the framings, &c., by the width ; keep the parts that are wreathed separate.

Note.—Wall strings are usually assumed as 12 inches wide.

Give the thickness of the strings, state if framed, rebated, and beaded, if sunk or double sunk, if moulded, if cut and mitred to risers, also if solid wreathed, or wreathed in thicknesses, or cylindrical mould with proper backings.

State if the circular parts are under 6 inches radius.

Extras.—Number of ramps (extra to the measurement).

" tongued angles.

" housings.

" splayed ends.

Handrails.

Per foot run.

Take the length along the middle of the rail. Keep separate the parts that are straight, ramped, wreathed, and circular.

Give the thickness, state if moulded or otherwise, and if the circular or wreathed parts are to well holes of less than 12 inches opening.

Extras.—Sinking for iron cores, straight or circular, at per foot run, unless included in the description of the handrail.

Number of handrail screws and fixing.

Number of scroll ends or moulded caps to newel.

Screw nut and joint to cap, &c.

Newels.

Per foot run.

Take the height, including the tenons.

Give the size, and state if single or double, turned or otherwise.

Extras.—Number of turned pendants.

Iron screw bolt, and fixing.

Balusters.

Per foot run.

Take the average height, including the tenons, if framed.

Give the size, and state if square or otherwise, if nailed on one or both ends, or dovetailed to step, or housed to handrail.

Extras.—Iron balusters if used instead of wood, and take the number of screws and fixing, stating if with flapped ends and if the heads of the screws are countersunk.

Fittings to Water-closets.

Per foot superficial.

For the seat and riser, if plain, take the extreme length and width (usually 20 inches) of the seat, to which add the height of the riser, and describe as with deal framed bearers.

For the flap and frame, take the length and width.

Give the thickness of the seat and riser, and also the thickness and labour on the flap and frame. State if mortice clamped, or mortice and mitre clamped, &c.

Take the skirting round the seat at per foot run, according to width and thickness, also the rounded corners.

Extras.—Number the seat and riser as "made to remove," with oak button blocks and brass cups and screws, or otherwise.

Take the rounded edge on front of seat and the moulded nosing under the flap at per foot run, and state if tongued, including groove on flap.

Take the hinges according to description.

The holes for the handle, stating if with mitred bead round the same.

Take the hole for the pan, and state if properly dished.

MISCELLANEOUS.

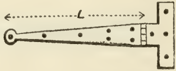
Shop fronts, shop shutters, counters, presses, cupboards, benches, church seats, pews, &c., are all measured on the foregoing principles, and it is therefore considered unnecessary to describe them in detail.

IRONMONGERY.

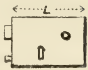
This includes all the brass and ironwork kept in stock by the ironmonger, and which is fixed by the joiner. It usually follows the joiner's work in the bill. The articles are for the most part sold by number, according to certain conventional sizes by which they are known, for example:

Butt, Backflap, and Parliament Hinges are known by their vertical height, as sketch.

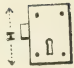
Cross Garnet and Strap Hinges, by the length of the strap measured from the knuckle



Rim, Mortise, Stock, Drawer, and Box Locks, Latches, &c., are known by the horizontal length.



Cupboard Locks, by the vertical height.



Padlocks, by the horizontal width when the lock hangs vertically.

Lock Furniture, by the diameter of the knob.

Barrel and Tower Bolts, by the length of the bolt.

Sash Pulleys, by the diameter of the pulley.

NOTE.—Locks are also described as "right" or "left" hand, according to the direction in which the bolt shoots when looking at the door from the outside.

Fixing ironmongery to hard woods should be kept separate from that fixed to soft wood.

PLASTERERS' WORK.

Plasterers' work is usually charged by the yard superficial.

Rendering to Walls.

Take the length of the walls, adding the passings at the angles, by the height; to inside work take the height from the top of the skirting grounds to the ceiling; deduct for the doors, windows, &c., and half the depth of the cornice; if the cornice is bracketed, deduct the whole.

Give the number of coats, and state if in mortar or cement, if gauged, set, floated and set, trowelled and prepared for paint, or as the case may be.

Take the run of cement angles, arrises, beads, and quirks extra.

Lath and Plaster to Ceilings.

Take the dimensions from wall to wall, deduct the cornice at one side and end only. If the cornices are bracketed, deduct the whole.

Give the number of coats, state if floated or set, or both, and if with putty.

State if single, lath and half, or double laths are used.

Take friezes, soffits, &c., according to description, by the foot superficial.

Measure raised panels extra by the foot superficial.

Take the mouldings on the panel by the foot run, according to the girth, and number the mitres.

Number pateras and other ornamental work, giving a full description of each.

Lath and Plaster Work to Partitions.

Measure as described for rendering. If a cornice. deduct one-third of the depth, or if bracketed deduct the whole; give description as directed for ceilings.

Cornices.

Take the length round the wall, and deduct one projection of the cornice each way, for the mean length. If the girth of the moulding from the ceiling to the wall line is 12 inches or under, take it by the foot run, stating the actual girth; and if over 12 inches, take it by the foot superficial.

If there are coves to the cornices, take them by the foot superficial.

Take enrichments by the foot run, stating the girth, and if undercut.

Number all the mitres to angles above four, stopped ends, &c., giving the girth, and stating whether the mitres are internal or external.

Stucco.

Take stucco work by the yard superficial; state if bastard, trowelled, on laths, or bricks, and prepared for paint, or as the case may be.

Take reveals and narrow widths by the foot run.

Take quirks, arrises, and beads by the foot run.

Skirting.

Take cement skirting by the foot run, stating the width, and how finished.

Number the angles.

Note.—If any of the foregoing work is circular it must be stated, and the circular parts kept separate.

Colouring, Limewhiting, &c.

Take colouring, distempering, and limewhiting by the yard superficial, according to description.

Take the run of cornices, and state the girth.

SMITH AND FOUNDERS' WORK.

Ironwork is usually charged by weight, and the dimensions are to be taken with this view. It does not matter by what method the surveyor proceeds with the measurement, if he obtains the exact contents in feet or inches.

Keep each article separate, according to description.

CAST IRON.—Take a pattern for each description of article of cast iron, and provide for altering it if it can be adapted to other castings.

Take as extras, chipping, filing, and fitting by the foot run. Holes drilled, to be numbered according to the thickness of the iron, and state whether done in *position* or at the works.

For heavy ironwork give the weight and height hoisted for each article, such as girders, iron joists, &c., and state by whom fixed.

Hoisting and fixing is sometimes described in the heading to the bill as included.

Eaves Gutters are measured at per foot run; the stopped ends and brackets are numbered extra.

Rain-water Pipe also at per foot run, the shoes, heads, and gratings being numbered extra.

WROUGHT IRON.—Measure by the foot superficial, according to thickness, and reduce to weight in the abstract.

Take the number of holes drilled for bolts, rivets, or otherwise, according to the thickness of the iron, and state if done in position.

Number the bolts when small, and the rivets according to size.

NOTE.—It is the practice with surveyors to take small articles of cast and wrought iron by number, but as all are sold by weight, the latter should be given when practicable.

PLUMBERS' WORK.

In measuring lead the dimensions should be carefully taken, the material being heavy and expensive, and small errors in the superficial dimensions become serious when reduced to weight

Lead, including the labour of laying to gutters, flats, and flashings, is usually charged by the lb., or by the cwt.; add, at intervals of about 8 feet, for laps, rolls, or drips; take

4 inches in length for each lap to flashings at about 7 feet intervals, 6 inches for each angle, and 8 inches in width for 2-inch rolls, also 8 inches to each drip when the lead is measured on the flat. Stepped flashings and soakers should be kept separate; the former are usually taken 12 inches wide and the latter 8 inches by 19 inches, according to the size of the slates or tiles.

Number the bossed and soldered ends to rolls.

Ridges and hips are usually taken 18 inches wide, and valleys 20 inches wide, and allow in the length for passings and laps as for flashings.

Take leadwork to cesspools, cisterns, sinks, &c., in the same manner as for gutters, &c., but separate.

NOTE.—Small cesspools and outlet pipes in gutters or lead flats are usually numbered, and the weight of the lead in them stated.

Take soldering to joints, angles, &c., and copper or other nailing extra at per foot run.

Take pipes at per foot run, according to the diameter and weight; take the joints extra. Soil pipes are usually out of 7 or 8 lb. lead.

Number all cocks and fixing according to size. Give an accurate description of each. State if with spanners or keys.

Take plugs, washers, and wastes, air traps, gratings, screw, or driving ferrules, &c., and fixing, according to description and size.

Give an accurate description of each water-closet, and mode of fixing, &c.

Number the D traps and service boxes, and state the weight of lead from which they are made.

Take making good to soil and other pipes extra.

WATER SUPPLY.

This is usually included in a separate bill.

Take iron cisterns by number, giving the size capacity in gallons, and the weight of the iron in the description; also state if galvanised, and the height at which they are to be fixed.

Extras—

Holes drilled for pipes.
Ball cocks and balls.
Trumpet-mouthed waste pipes.
Washers and wastes with fly nut.
Boiler screws.
Closet valves, } for water-closet cistern.
Ball levers, &c. }

Slate cisterns, although sometimes numbered, are usually measured in detail at per foot superficial.

Extras—

Run of groove and cement.

Number of iron tie rods (with description).

Holes, cocks, pipes, &c., as for iron cisterns.

Lead cisterns are taken as described in plumbers' work.

Wood covers to cisterns are measured by the foot superficial, and the man-holes numbered as extras.

Main Pipes are measured by the foot run, but inserted by weight in the bill.

The lead joints in socket pipes are usually numbered as extras.

Digging trenches for pipes in ordinary cases is measured by the foot run, and the depth stated.

Service Pipes, which are usually of wrought iron or lead, are measured and inserted in the bill at per foot run, the portions in the ground being kept separate from those fixed to walls; in the former the trench is taken, and in the latter the pipe is described as including wall hooks and fixing.

Supply Pipes to water-closets, sinks, baths, boilers, &c., should be taken by the foot run, giving the description and size, and taking the connections, unions, &c., extra.

Pumps and fixing are numbered and described. Suction and supply pipes (usually $\frac{2}{3}$rds of the diameter of the working barrel of the pump), and the connections to pump, rose end to suction pipe, wall hooks and fixing, &c., are all taken as extras.

PAINTERS,' GLAZIERS,' AND PAPERHANGERS' WORK.

Painter.—The rule observed in measuring painters' work is to take wherever the brush goes, allowing for edges in the height only and for returns in the width, and to charge by the superficial yard, except where it becomes necessary to work to a line, as in the case of skirtings, to prevent the floor or wall from being soiled, technically termed "cut in on both edges."

In describing painters' work, give the number of oils, and state if knotted, primed, or stopped, flatted, grained, or otherwise, if in common or ornamental colours. If the latter, give the name of each.

Note.—Common colours are produced from the mixture of lamp-

black, red-lead, Venetian red, English or Turkey umber, Spanish brown, or any of the common ochres, with white-lead and oil.

The ornamental colours are Prussian blue, indigo, mineral green, the rich reds, pinks, and yellow.

Take skirting, handrail, iron bar, eaves gutters, rain-water pipe, edges to shelves, edges of coping, strings, cornices, &c., by the foot run.

NOTE.—Strings, cornices, or other work, when done from a ladder or scaffold, should be kept separate.

Number sash frames (the outside only).

Sash squares (each side) per dozen.

Window sills, chimney pieces, newels, balusters, heads and shoes to rain-water pipes, door scrapers, coal plates and chains, air bricks, brackets, shutter bars, bolts, &c., each.

NOTE.—Take the inside of the sash frames with the linings at per foot superficial.

Work difficult to be measured, such as the capitals to columns and other ornamental work, should be numbered and described, giving as clear an idea of the amount of labour upon them as possible.

Letters or figures are sometimes numbered according to the height of each in inches, and described as plain or ornamental.

The usual plan is to take them by the inch run, measuring the height of the letters.

NOTE.—Ironwork is usually painted before and after fixing, which should be kept separate.

It is frequently the practice with surveyors to allow one-eighth of the superficial quantity of painting for edges, instead of measuring them, which admits of the quantity being obtained from the joiner's bill.

GLAZIER.—In measuring glass, take the dimensions from rebate to rebate each way, when the panes are square; if irregular or circular take the extreme dimensions as if they were square; keep all squares above 3 feet super. separate, according to the number of superficial feet in each. Glass in door panels should be kept separate if fixed in wash leather.

NOTE.—Surveyors usually measure the glass in windows by deducting 10 inches each way from the extreme dimensions taken for the window frame, or by measuring the external opening and deducting 2 inches from the width and 6 inches from the height.

Describe the glass according to the quality, and state whether stopped into old or new sashes.

Take all circular cuttings and risk by the foot run.

Take lead quarry lights separate, and number the spandril pieces to the heads of tracery windows according to size.

Glass in skylights and conservatories should be kept separate, and also if in long lengths.

Clips should be numbered as extras.

Glass tiles should be numbered according to size.

Cleaning windows, including risk of breakage, is usually charged by the dozen squares, each side being numbered, and large squares kept separate.

PAPERHANGER.—Paper for walls and hanging is charged by the piece, supposed to be 12 yards long, and although the actual length is seldom more than $11\frac{2}{3}$ yards, and width when fixed is supposed to be 21 inches, it is reckoned as if it were only 20 inches wide, therefore to find the number of pieces on a wall:

Measure the surface in superficial feet, deducting doors and windows and divide by 5 for the number of yards run of paper. This again divided by 12, or by 60 in one operation, will give the number of pieces.

NOTE.—In order to make a sufficient allowance for waste, allow one piece in seven when doors and windows are deducted; most surveyors divide by 54 instead of by 60.

Odd yards are charged as one piece.

Take in the same manner, and charge extra at per piece:

Pummicing and preparing the walls.
Sizing and varnishing hall paper.
Lining paper and hanging the same.

Take borders and hanging at per dozen yards run.

GASFITTER AND BELLHANGERS' WORK.

GASFITTER.—Take gas pipes, including fitting and fixing, by the foot run, according to material and diameter.

Take the number of elbows, crosses, T-pieces, reducing sockets, screw caps, outlets, &c., extra.

Main cocks with spanners according to size.

Brackets, pendants, &c., should also be numbered.

Take the meter (except when supplied by the Gas Co.), governors, siphon traps, pendants, &c., and fixing, according to description.

Provide shelf for meter.

Opening the ground, including filling in, is taken at per foot run, according to depth.

Holes broken through walls and made good are numbered according to the thickness of the wall, also connection of pipe with main and meter.

BELLHANGER.—Number each bell with pulls, &c., complete, state the floors on which the pulls are fixed, and the distance of the bells, their average weight, if with pendulums and indicators, also the gauge of the copper wire, and if in concealed zinc tubes or otherwise.

Take bell board, painting, and numbering, extra.

NOTE.—It is usual to provide for the attendance of a carpenter and a bricklayer to cut away for and make good after the gasfitter and bellhanger.

ABSTRACTING THE DIMENSIONS.

The several items after the dimensions have been squared and checked are to be abstracted as follows:—

Take the trades according to order, thus:

Extracts from specification.
Preliminary items and provisions.
Excavator.
Bricklayer.
Waller.
Mason.
Slater.
Carpenter and Joiner.
Founder and Smith.
Plasterer.
Plumber and water supply.
Glazier.
Painter.
Gasfitter and Bellhanger.

In each trade take—

1. The cubic quantities, commencing with the highest denomination, and the items of each according to value; those of least value first.

2. The superficial quantities according to denomination and value.

3. The lineal quantities according to denomination and value.

Lastly. The numbers according to value.

N.B.—Those items which include labour only should precede and be kept distinct from those which include both labour and materials.

MEMORANDA CONNECTED WITH BUILDERS' WORK.

EXCAVATOR.

The operations comprised in Earthwork are usually—

Getting,	Removing,
Filling,	Tipping,

Spreading.

Ground to be excavated may in general terms be classed as follows:—

1. Loose earth, sand, soft clay, and mud, that can be lifted with a shovel without digging.
2. Stiff earth, hard gravelly soil, hard clay, and chalk, that require "getting" by means of a pickaxe.
3. Rock and other hard ground, which require to be blasted.

Each class embraces a variety of soils more or less difficult to excavate.

For the purpose of valuation, ground is best described by the labour expended in excavating it.

As all ground has to be brought to nearly the same state before it can be filled into barrows or carts, the labour of filling may be assumed to be constant for earth of the same class, and the stiffness of the soil or difficulty of excavating it will affect only the number of "getters" required. Therefore the proportion which the latter bear to the number of "fillers" determines the relative amount of labour required to excavate any particular soil.

The unit to be adopted is the average quantity of earth which a man can fill into a cart or wagon per day of ten working hours, viz.:—

Earth of Class No. 1 = 22 cubic yards.
" " No. 2 = 18 "

Let the number of *Fillers* be represented by F, the number of *Getters* by G, and the proportion which represents the labour as compared with that on earth which requires no getting by N

Then $$N = \frac{F + G}{F}$$

In this manner excavation can be described as earth of 1, 1½, 2, or more men, according to the difficulty in getting it.

NOTE.—This method is not applicable to rock or other soils which require blasting.

Five feet in a face is the least width that should be allowed to enable each excavator to work with freedom.

In trenches, if not less than 2 ft. 6 in. wide, excavators can work without difficulty even to a considerable depth; in the latter case, most earths, clays, &c., will require to be timbered.

NOTE.—Although the cost of an excavation is determined by the quantity of earth that can be *got and filled* in a day, it is the quantity that can be *disposed* of at the "tip" which determines the rate of progress. On a railway embankment of which the top is 30 feet wide, the maximum quantity of earth that can be disposed of per day of 10 working hours is 1000 cubic yards. The *lead* or distance to which earth has to be removed is that from the centre of gravity of the cutting to that of the embankment or filling, and should be the shortest possible. The *leads* from other masses of cutting and filling should not cross.

Clean dry SAND and GRAVEL in excavation will retain a vertical face for a short time without falling in	= 0 to 1 foot.
MOIST SAND and ordinary SURFACE MOULD, ditto	= 1 to 3 feet.
LOAMY SOIL well drained, ditto	= 5 to 10 "
CLAY well drained, ditto	= 9 to 12 "
COMPACT GRAVELLY SOIL, ditto	=10 to 15 "
ORDINARY EARTH or CLAY will stand for a short time in embankments at a slope of..	1 to 1
If well drained it will stand permanently at a slope of	1½ to 1
If imperfectly drained it may stand at a slope of	2 to 1

CLAY retentive of water, if not kept dry, may slip at any slope.
CHALK and ROCK will stand vertically.

NOTE.—When the height of an embankment or depth of a cutting is great, the flatness of the side slopes should be increased.

EARTH and CLAY increase in bulk about *one-fourth* when dug, but subside *one-fifth* in height, and decrease when formed into embankments *one-tenth* of the bulk from the solid.

SAND and GRAVEL increase *one-twelfth* when dug. Sand subsides in embankments *one-fourth* in height, and Gravel from *one-tenth* to *one-twentieth*, according to its coarseness.

Sand and Gravel decrease very slightly in bulk from the solid after being formed into embankments. The former, however, is liable to be washed away by rain, unless protected.

CHALK increases *one-third* to *one-half* of its original bulk, when excavated.

ROCK increases *one-half* to *four-fifths* of its original bulk when excavated.

RUBBLE STONE deposited under water and subject to the action of waves or tides, unless carefully packed, decreases *one eighth* to *one-twelfth* in bulk after a few years.

NOTE.—The cause of earth, clay, sand, &c., being less in bulk when in embankment than before excavation is due to the action of the weather.

A WHEELBARROW, light..	holds	$\frac{1}{18}$	yard cube.
" ordinary	"	$\frac{1}{14}$	"
" large (navvy).. ..	"	$\frac{1}{10}$	"
A DOBBIN CART	"	$\frac{3}{4}$	"
A ONE-HORSE CART (6 ft. × 3 $\frac{1}{4}$ ft × 2$\frac{1}{3}$ft.)	"	1$\frac{2}{3}$	"
An EARTH WAGON, small, filled to level of sides, as with gravel, sand, &c. ..	"	2	"
Ditto, ditto, when heaped as with earth or clay	"	2$\frac{1}{2}$	"
Ditto, large, filled to level of sides ..	"	2$\frac{3}{4}$	"
Ditto, ditto, heaped..	"	3	"

Traction.—The resistance offered by wheelbarrows, carts, or waggons, when drawn along a horizontal road with a velocity not exceeding four miles per hour, is proportional to the load directly, and inversely to the diameter of the wheels.

A BARROW, with wheel 18 in. diam., on hard, dry earth requires to move it	$\frac{1}{14}$	part of the weight.
Ditto, ditto, on a wooden plank ..	$\frac{1}{25}$	"
A CART, with wheels 4 feet diam., on hard, dry earth..	$\frac{1}{15}$	"
A WAGON, with wheels 2 ft. 9 in. diam., on ordinary contractor's rails (straight) in wet weather	$\frac{1}{80}$	"
Ditto, ditto, in dry weather	$\frac{1}{120}$	"
Ditto, ditto, on a well-made railroad..	$\frac{1}{280}$	"

The traction on an inclined road = that on a horizontal one *plus* the weight of the load and that of the vehicle multiplied by the rise and divided by the length of the road.

Loss of Strength of a Horse on Inclined Roads.

Strength on—		Strength on—	
level road	= 1·00	incline of 1 in 30	= ·88
incline of 1 in 100	= ·96	" 1 in 20	= ·81
" 1 in 80	= ·95	" 1 in 15	= ·73
" 1 in 60	= ·94	" 1 in 10	= ·56
" 1 in 50	= ·93	" 1 in 9	= ·40
" 1 in 40	= ·91	" 1 in 8	= ·20

The maximum distance to which earth can be wheeled in Barrows economically .. .. = 100 yards
Ditto, in Dobbin Carts .. .. = 300 „
Ditto, in ordinary One-Horse Carts .. .. .. = $\frac{1}{2}$ mile

When the distance is over half a mile it will be more economical to use wagons on rails.

A horse barrow-road cannot be economically worked for a less depth than 20 feet.

The Quantity of Excavation in Wells and Circular Shafts for Each Foot in Depth.

Diam.	Quantity.	Diam.	Quantity.	Diam.	Quantity.
ft.	cub. yards.	ft.	cub. yards.	ft.	cub. yards.
3	·2618	$5\frac{1}{2}$	·8799	8	1·8617
$3\frac{1}{4}$	·3072	$5\frac{3}{4}$	·9617	$8\frac{1}{4}$	1·9799
$3\frac{1}{2}$	·3563	6	1·0472	$8\frac{1}{2}$	2·1017
$3\frac{3}{4}$	·4091	$6\frac{1}{4}$	1·1363	$8\frac{3}{4}$	2·2271
4	·4654	$6\frac{1}{2}$	1·2290	9	2·3562
$4\frac{1}{4}$	·5254	$6\frac{3}{4}$	1·3254	$9\frac{1}{2}$	2·6253
$4\frac{1}{2}$	·5890	7	1·4254	10	2·9089
$4\frac{3}{4}$	·6563	$7\frac{1}{4}$	1·5290	$10\frac{1}{2}$	3·2070
5	·7272	$7\frac{1}{2}$	1·6362	11	3·5198
$5\frac{1}{4}$	·8018	$7\frac{3}{4}$	1·7472	12	4·1888

Notes on Shifting Earth, &c., on a Contractor's Railroad.

(From actual practice on large earthworks.)

Capacity of Wagons—

$$\left.\begin{array}{l} \text{Body} = 7'\ 0'' \times 7'\ 0'' \times 1'\ 6'' = 73'\ 6'' \\ \text{Above the sides} \\ \quad = 7\ \ 0\ \times 7\ \ 0\ \times 0\ \ 4\ \ = 16\ \ 4 \end{array}\right\} = 89'\ 10'' = 1 \text{ wagon load.}$$

In light material, with side boards raised 6 inches, the quantity is increased by .. 24 6

Maximum capacity .. .. = 114 4

Note.—*The wagons were timber built, and weighed 30 cwt. each without the load.*

Labour in Filling Wagons—

2 men filled 15 wagons of light earth per day = 25 cub. yds per man.
3 „ 21 „ „ = $23\frac{1}{3}$ „

Note.—*It was found that when three men were employed, the work done by each in filling the wagons was less than when two only were employed.*

Work done in Teaming—

Two horses took 5 wagons $\frac{3}{4}$ of a mile on a level railroad, and made 15 journeys per day of 10 hours.

Note.—*If the lead were only half the distance the same number of horses would be required to work the road, owing to the quantity to be disposed of at the "tip" being limited. If the lead were more than $\frac{3}{4}$ of a mile, a second set of straight-road horses would be required to keep the fillers at work.*

In addition to those on the "straight road," another horse was employed to make up the train of loaded wagons. When the lead is short the straight-road horses are employed for this purpose.

On a level railroad 2 horses are usually required for every 5 wagons If the road rises 1 in 80 or 1 in 100, 3 horses would be required for the same number of wagons. If the road is 1 in 30 a horse will be required to each wagon. Wagons will run down of their own accord on a gradient of about 1 in 120, and 2 horses will easily bring up on the same incline 5 empty wagons.

Work done in Tipping—

One horse tipped from 80 to 100 wagons per day. For this quantity 3 men were required at the tipping place, this number being found sufficient for embankments not less than 10 feet in height. With lesser heights the labour of clearing away the contents of the wagons became greater, and additional men were required.

The following is an analysis of work performed by a Government contractor in excavating and removing chalk in wagons

18 excavators, 2 men at the tip, 2 ,, laying rails, 1 breaksman, 1 boy shifting rails, 3 drivers and 3 horses,	Excavated, filled, removed, and tipped 16 sets of large wagons, of 6 in each set, in a day of 10 hours. Each wagon contained the *debris* of 2 cubic yards of solid chalk. The distance removed was 500 feet down an incline of 1 in 30.

In this work there was *one digger* and *two fillers* to each wagon.

There were 12 wagons altogether on the rails, viz. 6 wagons at the tip, and 6 at the cutting.

To obtain the cost there should be added to the above

$\frac{3}{11}$ths of 1 foreman excavator, 3 carpenters, 1 smith and helper.	This is the proportion for the above to the total number of men employed throughout the works.

To the above should be further added a proportion for "Agent's" time, "Office Expenses," "Use and Waste of Plant," &c., and "Contractor's Profit."

The following was performed at the same works, but the removal was by dobbin carts, the distance and incline being the same as in the last case, viz. 500 feet falling 1 in 30.

3 excavators, 1 driver and 1 horse,	Excavated, filled, removed, and tipped 54 dobbin carts of loose chalk in a day of 10 hours. Each dobbin cart held 16 cubic feet of chalk (measured in the solid before digging).

Add $\frac{1}{25}$th of 1 foreman excavator, 3 carpenters, 1 smith and helper,	The proportion of the above men to the total number employed.

Add, as in the previous case, Agent's time, Office Expenses, Use and Waste of Plant, and Contractor's Profit.

Rock Blasting.

Excavation in hard rock is usually performed by means of some explosive material inserted in a hole bored in the rock, and when ignited it loosens the mass and permits of its being broken up into pieces of the required size.

The diameter and depth of the hole varies with the quantity of rock to be loosened at each blast and also with the strength of the explosive used.

The quantity of rock loosened, other conditions being the same, is roughly proportional to the cube of the "line of least resistance," which is generally the shortest distance from the centre of the charge to the surface of the rock.

If $E =$ the quantity of the explosive in lbs., and
$L =$ the line of least resistance in feet, then

$$E = C L^3$$

$$\begin{aligned} C &= \cdot 032 \text{ blasting powder.} \\ &= \cdot 008 \quad \text{,,} \quad \text{cotton.} \\ &= \cdot 005 \text{ dynamite.} \end{aligned}$$

Ordinary blasting powder, 1 lb. of which occupies about 30 cubic inches, is ignited by means of a fuze, such as Bickford's "Patent Safety Fuze," which burns at the rate of about 2 feet per minute, varying slightly with each coil.

In estimating it is usual to allow $\frac{3}{4}$ of a lb. of powder to each cubic yard of solid rock; the actual quantity required will vary with the nature of the rock, the number of faces exposed, and its degree of compactness or looseness, the latter requiring most powder.

Blasting cotton and dynamite should be fired by percussion. Detonating tubes or caps are made for the purpose, which explode on being ignited either by an ordinary fuze or by a galvanic battery. Blasting cotton does not deteriorate by wet, and when in that state it can be exploded by a lump of dry cotton and a detonating fuze. According to Guttmann, in a train of gunpowder $\frac{3}{4}$ inch in diameter the explosion

travels at the rate of a little over 8 feet per second, but in a train of dynamite it travels over 16,000 feet in the same time.

NOTE.—Owing to the number of nitro-glycerine compounds in the market and their various explosive powers, it is not considered safe to give their comparative strengths for general purposes.

In boring granite rocks cast-steel jumpers require to be sharpened about once for every foot of hole bored, and steeled about once for every 15 feet of hole, the length of iron wasted being about $\frac{1}{10}$th of the depth bored. In some of the trap rocks, often met with in mining operations, the author has found the number of "sharps" and iron wasted to be more than double those for granite. In the softer rocks they would of course be much less.

CONCRETE.

Concrete, which is now much more extensively used in building than formerly, is well adapted for such works as foundations, backings to retaining walls, covering to arches, and in any situation where the stresses are chiefly compressive. For the faces of walls above ground it is not so well adapted, particularly for the thin walls of houses, owing to the minute cracks which appear on the surface from expansion and contraction after a few years' exposure to the weather. These cracks absorb rain-water which expands in frosty weather and causes the destruction of the face.

Steps, window sills, pavements, and copings to walls have been formed with fine Portland cement concrete in lieu of stone, for which purpose it is superior to Bath or Caen stone when properly made. If much sand be used in copings and window sills, the exposed faces should be protected by a coating of oil paint or tar.

Burnt ballast or breeze has been used with Portland cement for concrete in arches, upper floors, and landings, chiefly to save weight, as well as from the supposed additional strength given to the mass by the greater adhesion of the cement.

A serious difficulty attending the use of concrete where it has to bear a transverse stress, is that of ensuring the proportions and proper mixing of the materials, as well as care in placing the concrete in position to prevent partial setting, and consequently a disjointed mass instead of a homogeneous one, as calculated upon.

Concrete in damp situations should always be made with hydraulic lime or Portland cement.

The proportions usually adopted for the best lime or cement concrete are—

One part screened gravel or broken stone, $\frac{1}{3}$rd part of sand, and $\frac{1}{6}$th part of the lime (ground) or cement.

Or,

One part Thames ballast or unscreened gravel, to $\frac{1}{7}$ part of the lime or cement.

NOTE I.—The quantity of lime or cement in concrete should always be specified at so many *bushels* or *cubic feet* to a cubic yard of concrete. The system of specifying concrete in parts of the whole is most misleading and unreliable.

NOTE II.—One-tenth part of Portland cement in concrete may be considered as equivalent in strength to one-sixth part of the best ground lias lime.

Roman Cement is unfit for concrete in large masses, as it seldom hardens beyond a few inches in from the face. It is valuable, however, in tide work as a protection to concrete formed of Portland cement or lias lime, on account of the rapidity with which it sets.

An *expansion*, varying from $\frac{1}{8}$th to $\frac{3}{8}$ths of an inch for every foot in height according to the nature of the lime, takes place in concrete made with unslaked lime, which it retains permanently.

Concrete, if it has not commenced to set, should be rammed until the lime or cement flushes up to the surface. This, if the concrete is laid in thin layers, causes a decrease in height of about $\frac{1}{10}$th. Ramming is preferable to the old practice of throwing from a height. The crushing strength of Portland cement concrete is nearly in proportion to the quantity of cement.

Materials to 1 cubic yard of Concrete.

6 pts. clean shingle, broken stone, or screened gravel, 2 pts. sand, 1 pt. ground lias lime or Portland cement,	Require	Shingle, &c., 27 cub. ft. Sand 9 „ Lime or Cement 3·51 bushels. Water, 25 gallons.

NOTE.—As a rule, 1 cubic yard of broken stone or clean shingle is required to make 1 cubic yard of concrete, but if the sand be increased beyond the above proportion, the quantity of shingle required is diminished, although in a somewhat less ratio than the sand.

7 pts. Thames ballast or unscreened gravel, 1 pt. ground lime or cement	Require	Ballast, 33 cub. ft. Lime or Cement 3·67 bushels. Water, 30 gallons.

NOTES.—I. Thames ballast contains two parts of gravel to one of sand.

II. In practice $1\frac{1}{5}$th cubic yard of Thames ballast is allowed for each cubic yard of concrete, including waste.

III. The proportions of sand and lime or cement should be taken with reference to the bulk of the shingle or ballast before mixing, and not to that of the whole of the materials when added together.

IV. The quantity of water required to slake the lime and mix the concrete may be more or less than that given above, according to the means adopted for preventing waste.

V. A simple method of ascertaining the proper proportion of sand to the broken stone, shingle, &c., is to fill an ordinary mortar pail with water by means of a small jug and note the number required, then empty the pail and fill with the broken stone, &c., level with the top; fill again with water until it flushes to the surface, and the number of jugfuls required will give the proportion of sand to broken stone. Again, if the broken stone and sand are mixed in the proper proportions, fill the pail again with water, and the number of jugs required to flush up to the surface will be the proportion of cement, to which a small addition should be made.

Tar Concrete.—This is usually made with broken stone or gravel, the same as for ordinary lime concrete, but the size adopted varies from $\frac{1}{4}$ inch to $2\frac{1}{2}$ inches, according to the purpose for which the concrete is intended.

All the materials used in making tar concrete should be heated, or at all events made perfectly dry before admixture with the tar. The proportion of tar should be about 12 gallons to each cubic yard of concrete. If the tar happens to be too thin, some pitch should be added to bring it up to a proper consistency.

An addition of from $\frac{1}{2}$ to 1 bushel of well-dried and pounded chalk, or lime that has become inert, to every 12 gallons of tar, tends to harden the mass. In places where chalk or lime is not to be had, dried clay, brickdust, or pounded cinders may be substituted.

Voids in 1 Cubic Yard of Materials used in Concrete.

		cub. ft.
Pit sand, fine	=	6·35
Thames ballast, unscreened	=	9·18
Sea sand, coarse	=	10·00
Sea gravel, over $\frac{3}{8}$-inch mesh	=	10·20
Beach shingle, clean	=	10·00
Bricks, broken, $\frac{3}{4}$ to $2\frac{1}{2}$ inches diam., screened ..	=	12·47
Stone, broken, $1\frac{1}{2}$ inch ditto	=	11·50
" 2 "	=	10·90
" $2\frac{1}{2}$ "	=	10·30

BRICKLAYER.

In London and the surrounding counties brickwork is measured by the *rod* of $16\frac{1}{2}$ feet square, and reduced to the standard of $1\frac{1}{2}$ brick in thickness.

In other parts of England and by civil engineers as a rule, the *cubic yard* is used as the standard for measurement.

1 rod of brickwork $= 16\frac{1}{2}$ ft $\times 16\frac{1}{2}$ ft. $\times 1\frac{1}{8}$ ft. $= 306 \cdot 2812$ cub. ft. $= 11 \cdot 34375$ cub. yards.

NOTE.—In practice the rod is taken in round numbers = 306 cubic feet, or $11\frac{1}{3}$ cubic yards.

1 rod of brickwork = 272 superficial feet of the standard thickness of $1\frac{1}{2}$ brick.

In abstracting brickwork, to reduce *cubic feet* to *superficial feet* of the standard thickness of $13\frac{1}{2}$ inches, *deduct* $\frac{1}{9}$th.

To reduce *superficial feet* of brickwork 9 inches thick to the standard thickness, *deduct* $\frac{1}{3}$rd.

NUMBER OF BRICKS AND QUANTITY OF MORTAR IN WALLS, &c.

Thickness of Mortar Joint.	Gauge or Height of 4 Courses.	Per Rod.		Per Cubic Yard.	
		Bricks.	Mortar.	Bricks.	Mortar.
inch.	inches.	Number.	cub. ft.	Number.	cub. ft.
$\frac{1}{4}$	$11\frac{1}{2}$	4546	49	470	4·32
	12	4356		384	
	$12\frac{1}{2}$	4182		369	
$\frac{3}{8}$	$11\frac{1}{2}$	4546	71	470	6·26
	12	4356		384	
	$12\frac{1}{2}$	4182		369	

NOTE.—The quantity of mortar will be increased by about 11 cubic feet per rod if the bricks are formed with hollows, also some slight addition should be made for waste.

In practice the following are usually taken—

FACING, per foot super.	requires	7 bricks.	Bricks $= 8\frac{3}{4}'' \times 4\frac{1}{2}'' \times 2\frac{3}{4}''$.
GAUGED ARCHES, per foot super.	,,	10 ,,	
BRICKWORK, reduced ,,	,,	16 ,,	
,, in mortar to walls, per rod	requires	4356 stocks.	
,, laid dry	,,	5371 ,,	
,, in mortar	,,	4500 place	
,, laid dry	,,	5400 ,,	
,, ,, in wells, &c	,,	4900 stocks.	

BRICKNOGGING, on edge, per yard super.			requires	30 stocks.
„	laid flat	„	„	45 „
PAVING	„	„	„	30 „
„	on edge	„	„	52 „
„	laid flat	„	„	36 paving bricks.
„	on edge	„	„	82 „
„	laid flat	„	„	13 tiles, 10-inch.
„	„	„	„	9 „ 12
„	„	„	„	70 clinkers.
„	on edge	„	„	140 „
„	herringbone	„	„	136 „

NOTE.—Bricknogging is now seldom used, as the wood quarterings (or studs), &c. shrink in seasoning. Half-brick walls in Portland cement are much better and often cheaper.

The size of the mould used for making bricks varies in different localities, and even with different manufacturers. The length is usually from $9\frac{1}{2}$ to 10 inches, the width from $4\frac{3}{4}$ to 5 inches, and the depth from 3 to $3\frac{1}{4}$ inches. There is also a corresponding variation in the size of the bricks when burned. The shrinkage of the clay in drying and burning varies about $\frac{1}{8}$th to $\frac{1}{15}$th from the dimensions of the mould.

The normal size of a stock brick may be taken at $8\frac{3}{4}$ in. × $4\frac{1}{4}$ in. × $2\frac{3}{4}$ in. A facing brick at $9\frac{1}{4}$ in. × $4\frac{1}{4}$ in. × $2\frac{3}{4}$ in., and a Welsh fire-brick at 9 in. × $4\frac{1}{2}$ in. × $2\frac{3}{4}$ in.

About 64 cubic feet of clay (from the solid) are required to manufacture 1000 bricks.

1000 ordinary sized bricks closely stacked occupy about 56 cubic feet of space.

1000 old bricks cleaned and loosely stacked occupy about 72 feet.

Good London stock bricks, when freshly burned, should not absorb after 24 hours' soaking, more than about $\frac{1}{5}$th of their bulk of water. Inferior bricks will absorb as much as $\frac{1}{3}$rd.

A Bricklayer's HOD is 16 inches long, and the sides are each 9 inches wide.

„ „ is capable of holding 20 bricks, the number ordinarily carried is 12.

„ „ will hold $\frac{2}{3}$ cubic foot of mortar,

„ „ „ $\frac{1}{2}$ bushel nearly.

THE NUMBER OF BRICKS AND QUANTITY OF BRICKWORK IN WELLS AND CYLINDRICAL SEWERS FOR EACH FOOT IN DEPTH OR LENGTH.

	Half-Brick Thick.			One Brick Thick.		
	Number of Bricks.		Cubic feet of Brick-work.	Number of Bricks.		Cubic feet of Brick-work.
	Laid Dry.	Laid in Mortar.		Laid Dry.	Laid in Mortar.	
1·0	28	23	1·6198	70	58	4·1233
1·3	33	27	1·8145	80	66	4·7124
1·6	38	31	2·2089	90	74	5·3015
1·9	43	35	2·5035	102	82	5·8905
2·0	48	41	2·7979	112	92	6·4795
2·3	53	44	3·0926	122	100	7·0686
2·6	58	48	3·3870	132	108	7·6577
3·0	68	57	3·9760	154	126	8·8357
3·6	79	65	4·5651	174	142	10·0139
4·0	89	73	5·1541	194	159	11·1919
4·6	100	82	5·7432	214	176	12·3701
5·0	110	90	6·3322	234	192	13·5481
5·.	120	98	6·9213	254	209	14·7263
6·0	130	107	7·5103	276	226	15·9043
6·6	140	115	8·0994	296	242	17·0825
7·0	150	123	8·6884	316	260	18·2605
7·6	160	131	9·2775	336	276	19·4387
8·0	170	140	9·8665	358	292	20·6167
8·6	180	148	10·4556	378	308	21·7949
9·0	191	156	11·0446	398	326	22·9729
10·0	212	174	12·2227	438	360	25·3291

Burnt Ballast.

Clay is burned into ballast by first forming a core of dry wood around a central post, on which is spread about $\frac{1}{2}$ ton of coals, then a coat of clay about 6 or 8 inches thick. The whole is set on fire through a horizontal flue 8 or 9 inches in diameter, of bricks on edge or old drain pipes, leading from the outer circumference of the heap to the centre post, an opening on the upper side of the inner end being left for the purpose of firing and supplying air. When this mass of wood, coal, and clay approaches incandescence, other layers of clay and coal are heaped on until the size becomes inconvenient. The firing should be slow at first, to drive out the moisture, after which the heat may be urged until the whole is thoroughly burnt.

For a heap 14 feet diameter, the core of wood should be about 4 feet at the base and about 4 feet high.

From $\frac{3}{4}$ to 1 cwt. of coal is required to burn a cubic yard of clay, which must be worked into a homogeneous state after being dug, or, according to some authorities, about 11 cubic yards of breeze and 4 tons of coal, including large and small, are required to burn 100 cubic yards of clay.

1 cubic yard of clay measured in the solid before digging, when burned and broken up will occupy a space of $1\frac{1}{4}$ to $1\frac{1}{2}$ cubic yards, and will weigh a ton.

—

Lime.

For the purposes of the builder, lime may be classed as follows:—

1 *Rich or Fat Lime.*—Obtained chiefly from the mountain limestone, or the pure white (upper) chalk. This lime will not set in damp situations, and is adapted only for plasterers' and other work in the interior of buildings.

Mountain limestone when burned into quicklime loses weight (about $\frac{4}{9}$ths) and bulk; it swells again when slaked,

so that 1 cubic foot of the original stone (measured solid) becomes 3 cubic feet of slaked lime in powder, and requires for slaking a quantity of water equal to about the weight of the quicklime, and to reduce it to "putty" a further quantity equal to $\frac{4}{5}$ths of the weight of the quicklime.

Chalk lime does not increase more than about two or two-and-a-half times the bulk of the original stone, the ratio of increase varying with the weight of the stone before burning.

2. *Lime slightly Hydraulic.*—Obtained in England chiefly from the lower or grey chalk, as at Merstham, Dorking, Lewes, and Halling. This was formerly called "stone lime." It will not set, nor even harden, under water until after a great length of time, but for ordinary building in the open air it is well adapted. It increases in bulk after burning and slaking from 1 cubic foot of the solid chalk to $1\frac{3}{4}$ of a cubic foot of lime in powder; it requires water to slake it to the extent of about $\frac{2}{3}$rds of the weight of the quicklime.

3. *Hydraulic Lime.*—In England this is obtained from the beds of the blue lias limestone, chiefly situated at Lyme Regis in Dorsetshire, Keynsham in Somersetshire, Shipston and Rugby in Warwickshire, Barrow-on-Soar in Leicestershire, Aberthaw in Glamorganshire, the Halkin Mountain in Flintshire, besides other places in Lincolnshire and Yorkshire.

It was found by experiment that $1\frac{3}{4}$ ton of the "Halkin" limestone made 1 ton of lime as burned and drawn fresh from the kiln, which equalled by measure 16 bushels, and when slaked into powder it yielded 24 bushels.

NOTE.—During the works for the extension of the London Docks it was found, as stated in a paper on Hydraulic Mortar read before the Institution of Civil Engineers in 1858, that

100 tons of Lyme Regis blue lias stone yielded—
59·37 tons of quicklime,
1583 bushels of ground lime,
3063 ,, of slaked lime,
74 gallons of water per ton of quicklime were required for slaking,
1 ton of quicklime = 30 bushels,
,, = 26·66 ,, of ground lime.

When taken by weight it was also found that whether the lime was in lump or ground, the bulk of slaked lime produced was the same.

CEMENT.

The principal cements used in building are Roman and Portland. The former is a natural cement manufactured from the septaria nodules of the London clay formation. The latter is an artificial cement made from a mixture of chalk and

clay, in proportions varying in the white chalk districts from 25 to 30 per cent. of clay to the whole bulk, and in the grey chalk districts from 15 to 20 per cent.; it is burned in a kiln, and afterwards ground into a fine powder.

Roman Cement.—In burning it loses nearly $\frac{1}{3}$rd of its weight, of which it regains about $\frac{1}{14}$th part when ground.

It is considered that 10 bushels of the unburned stone will produce about 11 bushels of ground cement.

NOTE.—Roman cement requires for mixing about 5 gallons of water to each bushel, exclusive of waste. If fresh and without sand it sets within 10 or 15 minutes after it is applied, and attains its maximum strength in about 12 months. When mixed with sand it takes a longer time to set and is much reduced in strength.

When used in large masses of concrete or masonry, the face having become hard, the interior remains soft for a long time. In some concrete sea walls, built with Roman cement, the author found the interior quite soft after 3 years from the time they were erected, although the outer crust had become exceedingly hard.

Roman cement from its quick-setting properties is useful in tide-work and for other purposes to which a slower setting cement would not be suitable.

Roman cement deteriorates by age and exposure to the air.

The average breaking weight (in tension) of a specimen which has been immersed in water from the time of making is

At end of 7 days	= 90 lbs.	per square	inch.
„ 1 month	= 108	„	„
„ 12 months	= 144	„	„
„ 5 years	= 200	„	„

Portland Cement.—When good, is of a blue-grey colour; the fracture of an indurated block is dark and compact, that of inferior cement being rotten and clayey.

The weight varies from 108 to 120 lbs. per bushel; heaviness is frequently attained by coarse grinding. Fineness and weight combined indicate good quality.

Portland cement has been ground to pass through a sieve of 2500 meshes to the square inch, in which case the weight seldom reaches more than 110 lbs. per bushel. The limit of coarseness should be the passing through a sieve of 900 meshes to the square inch.

The cement which ultimately attains the greatest strength is usually the slowest in setting. Quick-setting cement, which is rather brownish in colour, has generally too large a proportion of clay in its composition, and often turns out weak and useless.

Too much lime or insufficient burning causes in Portland

cement a tendency to swell or "blow." This also takes place when the cement is very fresh and has not had time to cool.

Portland cement, if preserved from moisture, does not, like Roman cement, lose its strength by being kept in casks or sacks, but within a reasonable limit of time rather improves by age. Fresh cement, as a rule, sets more rapidly than that which is kept for some time.

Cement by itself is stronger than when mixed with sand. With 2 parts of sand it is only half the strength of neat cement, with 3 parts it is a third of the strength, and so becoming weaker in proportion to the addition of sand.

The following shows the average tensile strength (breaking weight) attained by Portland cement when immersed in water soon after it had set:—

At the end of	7 days	= 270	lbs. per square inch.
"	1 month	= 310	" "
"	3 months	= 775	" "
"	12 months	= 900	" "
"	5 years	= 963	" "

A minimum breaking weight of 350 to 370 lbs. per square inch after 7 days is now frequently required by engineers, and if the sample is kept in water during that time the strength is increased nearly 20 per cent.

NOTE.—The quantity of water required to mix a bushel of Portland cement for use is about 3 gallons, exclusive of waste. The quantity of water required in proportion to the gross bulk diminishes when sand is mixed with the cement, but if the water is taken in proportion to the cement only, the quantity required increases. The less water used in mixing Portland cement the better.

MORTAR.

The proportions of lime or cement and sand generally used in making each class of mortar for building are—

Fat lime	and sand	1 to 3	The lime is measured before slaking.
Grey chalk lime	"	1 to 2	
Lias lime	"	1 to 2	
Roman cement	"	1 to 1	
Portland "	"	1 to 2	

The quantities of materials required in making mortar for a rod of brickwork, with $\frac{3}{8}$-inch joints and height of four courses = 1 foot, are—

Proportions.	Materials.	Bushels.	Cubic feet.
1 to 3	Fat lime (in small lumps) ..	20	25·7
	Sand	60	77·0
	Water	30	38·5
1 to 2	Grey chlk. lime (sm. lumps)	29	37·2
	Sand	58	74·4
	Water	24	30·8
1 to 2	Blue lias lime (ground) ..	30	38·5
	Sand	60	77·0
	Water	20	25·7
1 to 1	Roman cement	39	50·0
	Sand	39	50·0
	Water	29	37·2
1 to 2	Portland cement	26	33·4
	Sand	52	66·7
	Water	17	21·8
1 to 3	Portland cement	19	24·4
	Sand	57	73·1
	Water	16	20·5
1 to 4	Portland cement	15	19·2
	Sand	60	77·0
	Water	15	19·2

NOTE.—The proportions of lime, cement, sand, and water, vary in practice. The table gives the average results of numerous experiments.

The quantities in the above table divided by *three* give the proportions required for 1 cubic yard of mortar nearly.

The following is an average of two experiments on blue lias lime mortar made in a mill at the Wigan Waterworks in 1857, as published in the 'Builder,' 2nd June, 1860—

6 cubic feet lime = 331 lbs.
12 ,, sand = 939 ,,
23·4 gallons water = 234 ,,

The result in mortar was 12·62 cubic feet, weighing 1476 lbs.

The lime was ground previous to being placed in the mill.

The mortar was soft enough for use when ground, but required from 5 to 6 gallons of water additional in one hour after grinding.

The following is an average of two sets of experiments on Portland cement mortar, as related by Mr. Grant in his paper read before the Institute of Civil Engineers in 1865:—

To make 1 cubic yard of cement mortar, required—

1 to 1	Cement	12·62 bushels.
	Sand	12·62 ,,
	Water	52 gallons.
1 to 2	Cement	8·37 bushels.
	Sand	16·74 ,,
	Water	40 gallons.
1 to 3	Cement	6·37 bushels.
	Sand	19·11 ,,
	Water	37·25 gallons.
1 to 4	Cement	5·12 bushels.
	Sand	20·48 ,,
	Water	42·5 gallons.
1 to 5	Cement	4·19 bushels.
	Sand	20·95 ,,
	Water	42·5 gallons.

NOTE.—It required $16\frac{1}{2}$ days of a bricklayer at one of the Spithead forts to cut a doorway through a 4 ft. $1\frac{1}{2}$ inch brick wall in Portland cement 12 months old = 111·7 feet cube, i.e. about 7 cubic feet per day. If the bricks are hard, such as Galt bricks, a bricklayer may not be able to cut more than 2 cubic feet per day.

Bricknogging requires—per yd. sup.

$\frac{3}{4}$ cubic foot mortar when flat.
$\frac{1}{2}$,, ,, ,, on edge.

Pointing Brickwork requires—per yd. sup.

Flat joint, $\frac{1}{6}$ cubic foot of lime mortar, or
$\frac{1}{8}$ bushel of cement.

Tuck $\begin{cases} \frac{1}{8} \text{ cubic foot of putty.} \\ \frac{1}{8} \text{ ,, of mortar.} \end{cases}$

A load of mortar = 1 cubic yard, and will fill 40 hods.

Table Showing the Value of Brickwork per Rod, according to the price of Bricks, &c.

Price of Bricks per Thousand.	Cost of Labour and Mortar per Rod								
	70s.	75s.	80s.	85s.	90s.	95s.	100s.	105s.	110s.
s.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
20	8 0 0	8 5 0	8 10 0	8 15 0	9 0 0	9 5 0	9 10 0	9 15 0	10 0 0
21	8 4 6	8 9 6	8 14 6	8 19 6	9 4 6	9 9 6	9 14 6	9 19 6	10 4 6
22	8 9 0	8 14 0	8 19 0	9 4 0	9 9 0	9 14 0	9 19 0	10 4 0	10 9 0
23	8 13 6	8 18 6	9 3 6	9 8 6	9 13 6	9 18 6	10 3 6	10 8 6	10 13 6
24	8 18 0	9 3 0	9 8 0	9 13 0	9 18 0	10 3 0	10 8 0	10 13 0	10 18 0
25	9 2 6	9 7 6	9 12 6	9 17 6	10 2 6	10 7 6	10 12 6	10 17 6	11 2 6
26	9 7 0	9 12 0	9 17 0	10 2 0	10 7 0	10 12 0	10 17 0	11 2 0	11 7 0
27	9 11 6	9 16 6	10 1 6	10 6 6	10 11 6	10 16 6	11 1 6	11 6 6	11 11 6
28	9 16 0	10 1 0	10 6 0	10 11 0	10 16 0	11 1 0	11 6 0	11 11 0	11 16 0
29	10 0 6	10 5 6	10 10 6	10 15 6	11 0 6	11 5 6	11 10 6	11 15 6	12 0 6
30	10 5 0	10 10 0	10 15 0	11 0 0	11 5 0	11 10 0	11 15 0	12 0 0	12 5 0
31	10 9 6	10 14 6	10 19 6	11 4 6	11 9 6	11 14 6	11 19 6	12 4 6	12 9 6
32	10 14 0	10 19 0	11 4 0	11 9 0	11 14 0	11 19 0	12 4 0	12 9 0	12 14 0
33	10 18 6	10 3 6	11 8 6	11 13 6	11 18 6	12 3 6	12 8 6	12 13 6	12 18 6
34	11 3 0	11 8 0	11 13 0	11 18 0	12 3 0	12 8 0	12 13 0	12 18 0	13 3 0
35	11 7 6	11 12 6	11 17 6	12 2 6	12 7 6	12 12 6	12 17 6	13 2 6	13 7 6
36	11 12 0	11 17 0	12 2 0	12 7 0	12 12 0	12 17 0	13 2 0	13 7 0	13 12 0
37	11 16 6	12 1 6	12 6 6	12 11 6	12 16 6	13 1 6	13 6 6	13 11 6	13 16 6
38	12 1 0	12 6 0	12 11 0	12 16 0	13 1 0	13 6 0	13 11 0	13 16 0	14 1 0
39	12 5 6	12 10 6	12 15 6	13 0 6	13 5 6	13 10 6	13 15 6	14 0 6	14 5 6
40	12 10 0	12 15 0	13 0 0	13 5 0	13 10 0	13 15 0	14 0 0	14 5 0	14 10 0

TABLE SHOWING THE VALUE OF BRICKWORK, &c., ACCORDING TO THE RATE PER CUBIC FOOT.

Price per Cubic Ft.	Price per Yard Sup. 4½-inch thick.		Price per Cubic Yard.			Price per Rod.			Price per Cubic Ft.	Price per Yard Sup. 4½-inch thick.		Price per Cubic Yard.			Price per Rod.		
d.	s.	d.	£	s.	d.	£	s.	d.	d.	s.	d.	£	s.	d.	£	s.	d.
¼	0	0·844	0	0	6¾	0	6	4½	6¾	1	10·781	0	15	2¼	8	7	6½
½	0	1·687	0	1	1½	0	12	9	7	1	11·625	0	15	9	8	19	6
¾	0	2·431	0	1	8¼	0	19	1½	7¼	2	0·469	0	16	3¾	9	5	4½
1	0	3·375	0	2	3	1	5	6	7½	2	1·313	0	16	10½	9	11	3
1¼	0	4·219	0	2	9¾	1	11	10½	7¾	2	2·156	0	17	5¼	9	17	7½
1½	0	5·062	0	3	4¼	1	18	3	8	2	3·000	0	18	0	10	4	0
1¾	0	5·906	0	3	11¼	2	4	7½	8¼	2	3·844	0	18	6¾	10	10	4½
2	0	6·750	0	4	6	2	11	0	8½	2	4·688	0	19	1½	10	16	9
2¼	0	7·594	0	5	0¾	2	17	4½	8¾	2	5·531	0	19	8¼	11	3	1½
2½	0	8·438	0	5	7½	3	3	9	9	2	6·375	1	0	3	11	9	6
2¾	0	9·281	0	6	2¼	3	10	1½	9¼	2	7·219	1	0	9¾	11	15	10½
3	0	10·125	0	6	9	3	16	6	9½	2	8·063	1	1	4½	12	2	3
3¼	0	10·969	0	7	3¾	4	2	10½	9¾	2	8·806	1	2	0¼	12	8	7½
3½	0	11·813	0	7	10½	4	9	3	10	2	9·750	1	2	6	12	15	0
3¾	1	0·656	0	8	5¼	4	15	7½	10½	2	11·438	1	3	7½	13	7	9
4	1	1·500	0	9	0	5	2	0	11	3	1·125	1	4	9	14	0	6
4¼	1	2·344	0	9	6¾	5	8	4½	11½	3	2·813	1	5	10½	14	13	3
4½	1	3·188	0	10	1½	5	14	9	12	3	4·500	1	7	0	15	6	0
4¾	1	4·031	0	10	8¼	6	1	1½	12½	3	6·188	1	8	1½	15	18	9
5	1	4·875	0	11	3	6	7	6	13	3	7·875	1	9	3	16	11	6
5¼	1	5·719	0	11	9¾	6	13	10½	13½	3	9·563	1	10	4½	17	4	3
5½	1	6·563	0	12	4½	7	0	3	14	3	11·250	1	11	6	17	17	0
5¾	1	7·406	0	12	11¼	7	6	7½	15	4	2·625	1	13	9	19	2	6
6	1	8·250	0	13	6	7	13	0	16	4	6·000	1	16	0	20	8	0
6¼	1	9·094	0	14	0¾	7	19	4½	17	4	9·375	1	18	3	21	13	6
6½	1	9·938	0	14	7½	8	5	9	18	5	0·750	2	0	6	22	19	0

TILING.

A plain tile measures $10\frac{1}{2}$ in. × $6\frac{1}{4}$ in. × $\frac{1}{2}$ in., and weighs about $2\frac{1}{2}$ lbs.

A pantile measures $13\frac{1}{2}$ in. × $9\frac{1}{2}$ in. × $\frac{1}{2}$ in., and weighs about $5\frac{1}{4}$ lbs.

Tiling requires—

Per square of 100	feet super.	4-in.	weather,	600 plain tiles
„	„	3½	„	700 „
„	„	3	„	800 „
„	„	10	„	180 pantiles.
„	„	11	„	164 „
„	„	12	„	150 „

1 square of plain tiling weighs, on the average, 15 cwt.
" pantiling " " 8 "
A plain tile lath is 1 inch wide and a ½ inch thick.
A pantile lath is 1¼ inch wide and 1 inch thick.
100 plain tile laths 5 feet long = 1 bundle.
12 pantile laths 10 feet long = 1 bundle.

1 bundle of laths 1½ hundred of nails 1 peck of tile pins 3 hods of mortar	to 1 square of plain tiling.
1 bundle of laths 1¼ hundred of nails	to 1 square of pantiling.

Asphalte.

The substance known as asphalte in England is a bituminous limestone, which is found in the Val de Travers, near Neufchatel, and also at Seyssel, on the French side of the Jura Mountains. The stone is of a liver-brown colour, irregular in fracture, and has a specific gravity of 2·114. It contains from 5 to 15 per cent., and sometimes 20 per cent., of the natural mineral tar—from 11 to 12 per cent. is the most suitable proportion for general purposes. If there should not be sufficient bitumen in the stone itself, the proportion can always be increased by the addition of mineral tar. The Seyssel stone ordinarily requires 7 or 8 per cent., and the Val de Travers 4 or 5 per cent., of tar to be added.

In the best quality the stone should be of pure carbonate of lime, uniformly mixed with the natural bitumen. When this is heated to a temperature equal to that of boiling water the bitumen becomes soft, and the whole mass crumbles into a partially coherent powder.

If this powder while hot be compressed either by rollers or ramming, it again unites and forms a mass as hard as the original rock, and superior to it in toughness. It is in this manner that the Val de Travers asphalte is generally applied to roads and pavements.

This mode of application is not convenient for covering roofs and arches, or for forming damp courses, for which purposes a certain proportion of grit is added; the powdered asphalte is then slowly heated in large caldrons, in which sufficient mineral tar has been melted to prevent the asphalte from calcining, and the whole mass kept in a state of agitation until thoroughly incorporated; it is then run into moulds 18 inches square and 6 inches deep, and forms a block weighing 125 lbs. When about to be used, these blocks are broken up into small pieces, and placed in the boiler, some mineral tar having first been melted in it. Asphalte and tar are then added in the proportion of 1 lb. of the latter to 112 lbs. of the former, the quantity of tar being increased if additional grit be required to make "coarse asphalte."

In hot climates the quantity of tar should be reduced as much as possible, and in cold climates it should be increased.

The caldrons or "pots" used by the Seyssel Asphalte Company hold about 5 cwt. of asphalte each, and require in ordinary weather to melt this quantity about 1 cwt. of coal, but in very cold or windy weather as much as 2 cwt. may be required. Coke should not be used, as it is injurious to the material, and tends to destroy the caldron.

It is reckoned that a pot of asphalte will cover 70 superficial feet $\frac{3}{4}$ inch thick, or 1 cwt. to every 14 superficial feet.

Two spreaders, 2 attendants, and 1 caldron man, will work 2 pots and empty them 3 times a day (= 6 pots in all); the fires being lighted at 4 A.M., so as to be ready for the spreaders at 6 A.M.

The following are the thicknesses usually adopted in practice:—

Roads and streets (Val de Travers)	= $1\frac{1}{2}$ to 2 inches.
Floors, roofs, &c. (Seyssel)	= $\frac{3}{4}$ inch.
Damp courses	= $\frac{3}{8}$ to $\frac{1}{2}$ inch.

The weight of the block asphalte per *inch* in thickness is—

Without grit	9·25 lbs.	per foot super.
"Fine gritted"	13·0	,, ,,
"Coarse gritted"	12·3	,, ,,

Repairs can be effected and holes cut in asphalte already laid by pouring some of the hot stuff on the part, by means of which it is rendered soft.

Artificial Asphalte.—To 5 parts of coal-tar which has been boiled until freed from naphtha, add 6 parts of finely powdered chalk and 5 parts of fine sand, both perfectly dry. The mixture is then to be boiled until the ingredients are thoroughly incorporated, and while hot it is to be poured over the surface to be covered, and spread in the same manner and in the same thickness as the natural asphalte, the joints being made good with a hot iron.

When the composition has become too brittle from over-boiling, more tar should be added. Where chalk is not attainable, fine sifted slaked lime may be substituted, but the former is preferable.

WALLER AND MASON.

A quarryman will be able to turn out per day from 5 to 8 tons of limestone and other stratified rock, and from $\frac{1}{2}$ to 1 ton of granite.

100 cubic feet of solid stone, if broken into pieces of various sizes so that some may fit into the interstices of the others, will = 130 cubic feet.

Or, if the size be tolerably uniform, they will = 180 cub. ft.

1 ton of ordinary rag or limestone for rubble work will = about 23 cubic feet in bulk.

Rubble Masonry, when built in courses, requires per cubic yard about 35 cubic feet of stone, including waste, and $6\frac{1}{2}$ cubic feet of mortar, but in random and common uncoursed rubble work 33 cub. ft. of stone and 9 cub. ft. of mortar are required.

Flint Work.—22 bushels (= 1 ton) of rough flint, with 1 bushel of split flints to every yard superficial of face, and 8 cubic feet of mortar, will build 1 cubic yard of flint walling.

Ashlar Masonry requires for every cubic foot about $1\frac{1}{10}$ cubic foot of undressed stone, and from $\frac{1}{8}$ to $\frac{1}{12}$ cubic foot of mortar.

Pointing Ashlar Masonry requires per yard run of joint from $\frac{1}{20}$ to $\frac{1}{30}$ of a cubic foot of mortar, according to the thickness.

Absorption of Water by Stone.

(Dry.)

Granite	$\frac{1}{200}$ to $\frac{1}{400}$	of its volume.
Limestone, compact . . .	$\frac{1}{100}$ to $\frac{1}{200}$	,,
Kentish Rag, limestone . .	$\frac{1}{70}$	,,
Sandstone, compact . . .	$\frac{1}{10}$ to $\frac{1}{20}$	,,
Portland Stone, oolite . .	$\frac{1}{8}$	,,
Bath Stone ,, ...	$\frac{1}{6}$	,,
Chalk	$\frac{1}{5}$	,,

Comparative Resistances to Wheel Traffic of the following Descriptions of Granite, viz.:—

Guernsey	1·00	Dartmoor	3·45
Peterhead blue.. ..	2·18	Aberdeen blue.. ..	3·75
Aberdeen red	2·65		

Preservation of Stone.—Some of the Oolites, like Bath and Portland Stone, are easily affected by the atmosphere of large towns. Several remedies have been proposed from time to time, but none have been permanently successful. A coat or two of white-lead paint or solid paraffin dissolved in coal tar naphtha, in the proportion of $1\frac{1}{4}$ lb. to the gallon, applied warm, is probably as good as any.

SLATER.

The slates used for roofing in England are chiefly obtained from North Wales, Westmorland, and Cornwall. Slates are also obtained from the north of Scotland, but they are inferior to English and Welsh slates, owing to the quantity of iron pyrites which they contain. Excellent slates are obtained from Killaloe and Valentia in Ireland.

Good roofing slate should be compact and sonorous, incapable of absorbing or retaining much moisture, hard and rough to the touch, those which feel smooth and greasy being usually inferior for roofing purposes.

A common test for roofing slate is to place one on edge to half its depth in water, and if in, say 12 hours, the water approaches the top of the slate it should be rejected. If it does not rise beyond $\frac{1}{8}$th of an inch the slate may be considered as practically non-absorbent.

Another method is to weigh a well-dried slate, and after soaking it for 12 hours in water to weigh it again; the difference in weight will show the quantity of water absorbed.

A good slate after 12 hours' soaking in water should not have imbibed more than $\frac{1}{200}$th part of its weight. The best slates do not absorb water to any appreciable extent.

Copper, composition (7 copper to 4 zinc), or galvanised iron nails should be used for slating; if, however, common iron slating nails be used, they should be heated and immersed in boiled linseed oil.

$1\frac{3}{8}$-inch nails should be used for small slates, such as "Doubles."

$1\frac{1}{2}$-inch for medium-sized slates, such as "Countess"; and

$1\frac{3}{4}$-inch for "Duchess" and larger slates.

The *gauge* or margin of a slate is the portion exposed to the weather, and is equal to half the total length after deducting the lap.

Slates have been obtained as *thin* as $\frac{1}{16}$th of an inch; $\frac{1}{6}$th to $\frac{3}{16}$ths of an inch are the usual thickness for 1st Quality "Countess" and "Duchess" roofing slates. 2nd Quality often run from $\frac{1}{4}$ to $\frac{3}{10}$ths of an inch in thickness.

The *transverse strength* of good Bangor slate is more than double that of Yorkshire paving, and more than 5 times that of Portland stone. The strongest slate is that obtained from the Cambrian or Lower Silurian formation.

TABLE SHOWING THE AVERAGE SIZES OF SLATES AND THE PROPORTIONS USED IN ROOFING.

Name of Slate.	Size. inches.	Gauge. inches.	Number of Squares covered by 1200.	Number required to cover 1 Square.	Nails required per Square.	
					Iron, Number.	Copper, lbs.
Doubles	12 × 8	4½	2·85	420	840	5
Ditto	13 × 6	5	2·38	504	1008	5½
Ladies	14 × 12	5½	5·26	228	456	2¼
Ditto	16 × 8	6½	4·14	290	580	3¼
Viscountesses	18 × 10	7½	5·94	202	404	2½
Countesses	20 × 10	8½	6·74	178	356	2
Marchionesses	22 × 12	9½	9·09	132	264	1¾
Duchesses	24 × 12	10½	10·00	120	240	1½
			Covered by 1 Ton.			
Imperial	30 × 24	13½	2·5	48	96	1½
Rags	36 × 24	16½	2·2	40	80	1
Queens	36 × 24	16½	2·5	40	80	1

NOTE.—The sizes of slates of the same name vary in different localities. The dimensions should always be quoted where the size is important. The Table includes $\frac{1}{20}$th for waste.

CARPENTER.

TIMBER.

The natural order *Coniferæ* supplies the most important woods used for building in Europe and North America; many of the species are widely distributed. The timber can be obtained in large sizes, is easily wrought, and moderately durable.

From the *Amentaceæ* is obtained the oak, chestnut, and beech, which as a rule are hard and durable woods.

The *Aleineæ* supplies the ash; *Ulmaceæ*, the elm; *Meliaciæ*, mahogany; and *Verbenaceæ*, teak. Many of the Asiatic and Australasian woods are either imperfectly classified, or they belong to natural orders containing few species, and often confined to comparatively limited areas.

NORTHERN PINE (leaves in pairs) *Pynus Sylvestris.*—Much confusion has arisen among architects and builders owing to the absurd practice of naming this timber after the ports of shipment, and also from confounding the pines (*pinus*) with the firs (*abies*), although they belong to distinct genera, the former having their leaves long and clustered in twos, threes, fives, or sevens, according to the species, while the latter have their leaves single and short. The cones and general appearance of the trees are also dissimilar. The *P. Sylvestris* is essentially a wood of northern climates, and will thrive at greater elevations and in higher latitudes than even the fir, hence the term "Northern Pine" given to it by the author in his edition of Tredgold's 'Carpentry,' and also adopted throughout this work.

Northern pine is very generally used for all purposes of carpentry and joinery. It is exported under the name of "Red Wood" from the Prussian, Russian, Swedish, and Norwegian ports in the Baltic Sea. Some of the largest logs are obtained from Stettin. Those from Dantzic are from 11 to 18 inches square, and from Riga 11 to 14 inches square; both can be had in lengths from 18 to 40 feet. As a rule the timber exported from Memel is of smaller section and shorter length, being seldom more than 13 inches square and 35 feet long.

Swedish and Norwegian timber is generally of smaller scantling than that obtained from either Russian or Prussian ports, being seldom over 1 inches square, and frequently as small as 8 or 9 inches square.

The Swedish timber, according to Mr. Laslett, is very liable to heart and star shakes, and not unfrequently to the cup shake.

Northern pine is also exported in the form of planks, deals, and battens; of those sent to England, the first are usually 11 inches wide, the second about 9 inches, and the last 7 inches wide, and of any length that can be procured over 8 feet, shorter lengths being classed as "ends." The usual thickness is from 2 to 3 and sometimes 4 inches.

RED PINE (*P. rubra*), erroneously called *P. resinosa* by Aiton and the older botanists; YELLOW PINE (*P. mitis*), both grown in North America. They are two-leaved like the *P. Sylvestris.* The red pine has a clean fine grain, which works up well, and is not so apt to shrink or warp in seasoning as most specimens of the *P. Sylvestris.* It has not much sap, and is fairly free from knots, and in many respects it may be considered a desirable wood for the purposes of the joiner, although not equal in some respects to the best description of the *Pinus Sylvestris.*

Red pine is imported in logs from 16 to 50 ft. in length, and 10 to 18 in. square.

PITCH or GEORGIAN PINE (*P. Australis*) has its leaves in threes, and is also known as the long-leaved pine. It is obtained chiefly from the swampy districts of the Southern States of N. America, and is shipped from the ports of Pensacola, Savannah, and Darien. It has often been confounded with the *P. rigida*, also called Pitch Pine in America. The logs are usually from 11 to 18 in. square, and from 20 to 45 ft. in length.

The wood, which is full of resin, is of a reddish-white or rich brown colour, regular and straight in the grain, looks well when varnished, and is sometimes used in joiners' work, particularly for the woodwork of churches. It is durable in most situations, but being more difficult to plane than most of the pines, it is expensive for joiners' work.

WHITE PINE (leaves in fives) *P. strobus*, known in England as "yellow pine," is one of the most useful woods grown in America, and is there applied to all the purposes for which "northern pine" is used in Europe.

Although not very durable in England when exposed to the weather, it lasts for a long time in the comparatively dry climate of America. The wood is light, soft, remarkably free from knots, and easily wrought, it holds glue, but does not hold nails very well. It is also rather liable to dry rot.

White pine is easily recognised when planed, by the minute elongated dark specks over the surface, which are seen in the direction of the grain.

It is exported in logs from 14 to 26 in. square and from 18 to 40 ft. in length, and in deals from 2 to 3 in. thick, and from 9 to 24 in. wide, by a length of from 10 to 20 ft.

White pine deals are usually classed as "bright," which are passed direct from the saw mills for exportation, and "floated," which are brought from long distances on rafts, and become slightly discoloured in transit. "Dry floated" deals are those which have been stacked and dried before shipment. Each class being sorted into 1st, 2nd, and 3rd, according to quality

WHITE FIR, or SPRUCE, or FIR PROPER (leaves single), *Abies excelsa*, known in the English market as "white deal." It is produced in the same regions as the northern pine, and grows much taller and straighter. White fir is seldom imported to this country in logs, but mostly as deals and battens from 2 to 3 in. thick, 5 to 9 in. wide, and sometimes 11 and 12 in. wide. The tree is usually cut into lengths of about 12 ft. each.

White deal may be obtained of fine grain, and is capable of taking a high polish, but generally this timber is rather too coarse for the finer descriptions of joiners' work. It is often knotty, and liable to snap on the application of a sudden stress. The shrinkage in seasoning is much less than that of northern pine, a quality which renders the wood useful for flooring boards, panelling, backing to veneered work, &c. It unites well with glue, and is tolerably durable, but inferior in this respect to northern pine; it is, however, rather more difficult to work than the latter. For floors and panels Christiania white deal is considered the best; that produced from the lowlands of Norway warps and splits in drying. Gottenburg deals are stringy, and fit only for packing cases. Petersburg white deals are said to shrink and swell with the weather, even after being painted.

The wood is much whiter in colour than the northern pine, and the sapwood cannot be easily distinguished from the heartwood.

The American WHITE SPRUCE, *Abies alba*, which is a mere variety of the *A. excelsa*, is largely imported into England from Canada and New Bruns-

wick, the latter being somewhat inferior. The thickness of the deals is usually 3 inches, and the width from 7 to 11 inches, and may be obtained up to 15 inches; the lengths are from 8 to 21 feet. American white spruce is not so resinous nor so durable as that from Norway, it is more liable to twist in drying; it is, however, tougher and weighs less than the Norway spruce.

BRITISH OAK (*Quercus pedunculata*) is one of the strongest and most durable woods grown in Europe. It was formerly much used for roof and floor timbers, but for these purposes it has long since in a great measure been displaced by pine and fir, which are much cheaper, and can be procured in more convenient sizes. The leaves of the tree have short foot-stalks (*petioles*), and the acorns long ones; the wood has a slightly reddish tinge, is comparatively free from knots, the larger medullary rays are very numerous, the grain is fine and tolerably straight; the wood will cleave easily into pales or laths, and if it were not for its comparative scarcity there are few woods that would excel it for general building purposes. It can be procured in logs of 9 inches square by 10 feet long, to 20 inches square and 26 feet long, the larger sizes being of course the most expensive and difficult to procure.

The *Q. sessiliflora*, or sessile fruited oak, is another species grown in England, and although the wood is somewhat softer when young, it is nearly if not quite equal to the former. The foot-stalks of the leaves are long, often nearly an inch in length, while those of the acorns, as the name of the species implies, are short or almost entirely absent. The colour of the wood is darker and more uniform than that of the *Q. pedunculata*. The grain is also less varied, the larger medullary rays are not so abundant, and when old the gloss and smoothness of the grain makes it resemble chestnut. It is liable to warp and become shaky in seasoning, it is also tough and difficult to split into laths or pales.

BALTIC OAK (*species not clearly determined*) is chiefly imported from Dantzic, Stettin, and Memel. It may be distinguished from the British oak, to which it is somewhat inferior, by the comparative straightness of its grain and freedom from knots. The wood is close grained and compact, although sometimes rather short.

The Memel variety is finer in grain than the Dantzic.

The logs are from 10 to 16 inches square, and from 18 to 30 feet long. The planks vary in size from 2 to 8 inches thick, 9 to 15 inches wide, and from 24 to 35 feet in length.

Oak is also exported from Norway under the name of "clapboard," and from Holland under the name of "Dutch wainscot." The latter may be distinguished by the absence of the white-coloured streaks which cover the surface of the former in all directions.

Clapboard and wainscot are less liable to warp and split when in thin boards than English oak; they are, however, much softer, and in other respects inferior to it.

AMERICAN WHITE OAK (*Q. alba*).—This is the species usually imported into England as "American oak," and can be obtained in larger sizes than any of the European oaks. The logs vary from 12 to 24 inches in thickness, and from 25 to 40 feet in length.

The wood has a whitish-brown colour with a red tinge; it is tough and pliable, the grain is straighter than that of English oak. It is inferior to the latter in durability.

All oak shrinks more or less in seasoning, and in fact every time it is planed, but in Mr. Laslett's experience white oak shrinks less than any other and almost without splitting, and he considers it to be the best

foreign oak timber of straight growth and large dimensions for constructive purposes that has ever been imported.

Oak should not be placed in contact with iron, as it leads to the decay of both.

BEECH (*Fagus sylvatica*) and ELM (*Ulmus campestris*) are not generally used in building, except for piles in foundations. Both are very durable in a dry state, or if kept constantly wet, particularly the latter, but when they are exposed to the weather they are not nearly so durable.

MAHOGANY (*Swietenia mahogani*) is a well-known wood used for furniture and the interior fittings of buildings. The tree is often found with a solid trunk 40 feet high and 6 feet in diameter. The wood called "Spanish mahogany" comes from Cuba and other islands in the West Indies, and that called "Honduras" from Mexico, the countries surrounding the Bay of Honduras, and Brazil. Mahogany does not last long when exposed to the weather, but is very durable when kept dry. The wood is tough, and it shrinks and warps less than most other timbers. Spanish mahogany is the hardest and darkest in colour, and the most beautiful in grain. Mahogany is known in the markets as "plain," "veiny," "watered," "velvet-cowl," "bird's-eye," and "festooned," according to the appearance of the vein formations.

The logs are usually from 11 to 24 inches square, and from 18 to 35 feet long, except those from St. Domingo, which are seldom more than 10 feet long, and 13 inches square. Honduras mahogany is usually much softer and lighter in colour than Spanish. The wood is, however, strong, tough, and flexible, when fresh, although it becomes somewhat brittle when dry. The grain is smooth and silky, the wood works up well, and does not shrink or warp much in seasoning. The sizes of the logs are about the same as those of the Spanish mahogany.

TEAK (*Tectona grandis*) is one of the most useful timbers known. The chief supply at present comes from Burmah and Pegu, it also grows in Siam and Java. It often attains a height of over 100 feet, and a circumference of 10 feet; the more usual girth, however, is from 4 to 7 feet. The wood is rather variable in appearance and quality, depending much on the locality. The colour varies from a brownish yellow to deep brown; it is clean, straight grained, easily worked, and shrinks but little in seasoning; from the liability of its fibres to separate in a longitudinal direction, the axe, adze, auger, and plane must be employed with some caution. Owing to its possessing an essential oil, which acts as a natural creosote, teak is very durable in all situations; it does not corrode iron as oak does, and it can be used for any of the purposes to which pine and oak are applied. The wood, although much harder than pine, is not quite so hard as oak; expense is almost the only objection to its more frequent use in England. It is usually imported in logs 10 to 30 inches square, and from 23 to 40 feet long. Teak in the London markets is sorted according to size; logs of 15 inches square and upwards are classed as "A" size, those between 12 and 15 inches as "B," and smaller sizes as "C," damaged logs are classed as "D." One of the most valuable properties in tropical climates, possessed by teak, is its power of resisting the attacks of the white ant.

GREENHEART (*Nectandra rodiæi*).—A tree which belongs to the same family as the bay laurel and sassafras. It is obtained from British Guiana, and is used in England chiefly for harbour works, for which purpose it is well adapted owing to its durability, and the property, which the heart-wood is said to possess, of resisting the attacks of the *Teredo navalis* and *Limnoria terebrans*.

The wood is clean, hard, heavy, tough, and elastic, the grain is fine but not very even. From the sapwood to the heartwood the colour varies from a pale greenish yellow to a deep brownish purple. The wood possesses great strength, but owing to its liability to break up suddenly into splinters, it requires care in sawing.

Logs may be obtained from 12 to 24 inches square, and up to 50 feet long.

JARRAH (*Eucalyptus marginata*).—One of the gum trees. This species is found in Western Australia, where it grows to a height often exceeding 200 feet; large trees are liable to early decay at the heart, but sound timber can be obtained in logs up to 40 feet long, and 24 inches square.

The colour is a darker red than the other Australian gum trees, and is not unlike mahogany. The wood is hard, heavy, close grained, and rather brittle; it is liable to shrink and warp in seasoning. It takes a good polish, and may be used for furniture, but the property which recommends it most to the notice of the engineer and builder is that of resisting the attacks of sea worms and white ants, provided the timber is perfectly sound, and cut before the sap commences to rise. It is therefore well adapted for harbour works, and in tropical climates for railway sleepers and telegraph posts.

SITUATIONS IN WHICH THE FOLLOWING WOODS ARE DURABLE.

I. *Exposed to the Weather.*

Oak.	Hackmatack (N. America).
Cypress.	Red Larch "
Yew.	Greenheart (B. Guiana).
Ironwood (S. Africa).	Mora "
Sneezewood "	Chestnut.
Teak.	Larch (Europe).
Sabicu (E. India).	Beech.
Hornbeam.	Sâl (E. India).
Tuart (Australia).	Sissoo "
Iron Bark "	Ash.
Jarrah "	Kauri (N. Zealand).
Cedar (W. India).	White Poplar (Abele).

II. *In Water.*

Elm.	Plane (N. America).
Alder.	Acacia.
White Cedar.	Northern Pine.

III. *Dry.*

Mahogany.	Grey Poplar.
Walnut.	Sycamore.
Maple.	Willow.
Fir (Norway).	Yellow-wood (S. Africa).
Pine, Red.	Poon (E. India).
" White.	Mango "
" Pitch.	Birch.
Black Poplar.	

Colonial Woods which are said to resist the Attacks of the White Ants.

(According to Mr. Britton.)

America—Butternut, pitch pine (partially).
Australia—Jarrah, Huon pine.
British Guiana—Greenheart, determa, cabacalli kakaralli.
Ceylon — Ebony, ironwood, palmyra, gal-mendora, paloo cohambe.
India—Cedar, sâl neem, sandal, erul, nux vomica, teak.

Note.—Ants will bore through teak to get at yellow pine.

Trinidad—Sepe.
West Indies—Bullet wood, lignum vitæ, quassia wood.

Decay and Preservation of Timber.

The modes of decay in timber which chiefly interest the builder are those known as "wet rot" and "dry rot," both of which are indirectly due to the presence of moisture: in the former, by assisting the decomposition of the tissues of the wood, particularly those of the alburnum or sapwood; and in the latter by aiding the growth of certain cryptogamia, which obtain their nutriment from the substance of the wood.

The reduction of the natural moisture in the wood itself, which is effected by proper seasoning, and the prevention of the access of external moisture by a coating of some impervious substance, such as paint or tar, tend to prevent wet rot.

The same means will also tend to prevent dry rot, but with the latter there is the peculiarity that an excess of moisture is unfavourable to the growth of the fungus which feeds on the wood also that when the circumstances are favourable, such as a moderate degree of moisture, which most woods possess in themselves, and the existence of a damp, warm, stagnant atmosphere, no mere coating of paint will prevent the *mycelium* of the dry-rot fungus from penetrating to the interior of the wood. This once effected, its destruction is rapid.

There are several species of fungi which attack wood; the most common appear to be the *Merulius lachrymans* and the *Polyporus hybridus*. The former attacks chiefly fir and pine, and the latter oak. Both species are sessile, and belong to the order Polyporei, which differs from the Agaricini, to which the common mushroom belongs, by the former having pores on the surface of the pileus, instead of gills as on the latter.

It is in these pores or gills that the *spores* are found which reproduce the parent plant.

The following processes have been suggested from time to time, with the view of destroying and preventing the spread of the dry-rot fungi:—

Bethell's Process.

This appears to be one of the most successful means yet adopted for preserving wood from dry rot, and even wet rot, or the attacks of the white ant and *Teredo navalis*. It consists in impregnating the substance of the wood with the oil of tar called *creosote*, from which the ammonia has been expelled, the effect being to coagulate the albumen, and thereby prevent its decomposition, also to fill the pores of the wood with a bituminous substance that excludes both air and moisture, and which is noxious to the lower forms of animal and vegetable life. In adopting this process, all moisture should be dried out of the pores of the timber. Fir or pine, while warm from the drying-house, may be immersed at once in an open tank containing hot creosote oil, when it will absorb about 8 or 9 lbs. per cubic foot. For hard woods, and soft woods which are required to absorb more than 8 or 9 lbs. of creosote per cubic foot, the timber should be placed in an iron cylinder with closed ends, and the creosote, which should be heated to a temperature of about 130° Fahr., forced in with a pressure of 170 lbs. to the square inch. The heat must be kept up until the process is complete, to prevent the creosote from crystallising in the pores of the wood. By this means the softer woods will easily absorb from 10 to 12 lbs. of the oil per cubic foot.

The most effective method, however, is to exhaust the air from the cylinder after the timber is inserted, then to allow the oil to flow in, and, when the cylinder is full, to use a force pump, with a pressure of 150 to 200 lbs. per square inch, until the wood has absorbed the requisite quantity of oil, as indicated by a gauge which should be fitted to the reservoir tank.

The oil is usually heated by coils of pipes placed in the reservoir, through which a current of steam is passed.

The quantity of creosote oil recommended to be forced into the wood is

For railway sleepers, telegraph poles, and other purposes on land	8 to 10 lbs. per cub. foot.
For piles, jetties, and other marine works	12 lbs. ,,

Into oak and other hard woods it is difficult to force, even with the greatest pressure, more than 2 or 3 lbs. of oil.

For piers and jetties, if the wood is to be creosoted, it is better to use the softer or even inferior descriptions of pine, if full of sap, which will absorb more of the oil; as in such cases the wood requires to be protected more from the teredo and wood-boring crustaceans than from the weather.

Creosote is said to render wood brittle and liable to snap suddenly under a severe strain.

Boucherie's Process.

This consists in impregnating the timber with a solution of 1 part by weight of *sulphate of copper* to 100 parts of water, as follows:—A water-tight cap is placed on one end of the log to be saturated, and the solution is introduced within it by a flexible tube. The pressure required not being more than 15 to 20 lbs. on the square inch, may be obtained by

simply raising the tank to a height of 30 or 40 feet from the ground. On this pressure being applied, the sap runs in a stream from the opposite end of the log. A piece of prussiate of potash rubbed on the end of the log will show if the solution has penetrated the entire length or not. for, on coming in contact with the sulphate of copper, it leaves a deep brown mark on the wood. Margary, in his process, used sulphate of copper in the proportion of 1 lb. of the salt to 8 gallons of water, in which the wood was merely steeped until thoroughly saturated, which was supposed to take 2 days for every inch in the thickness of the wood.

Boucherie also used the impure pyrolignite of iron, which was found not only to preserve the wood from decay, but also to harden it.

Kyanising.

The timber is immersed in a saturated solution of corrosive sublimate (perchloride of mercury) in a wooden tank, put together so that no metal of any kind can come in contact with the solution.

One pound of corrosive sublimate to 10 gallons of water is used when a maximum strength is required, and 1 lb. to 15 gallons of water when a minimum, according to the porosity of the timber; with the latter proportion, 1½ lb. will be sufficient for a load of timber of 50 cubic feet.

Corrosive sublimate dissolves best in tepid water. It has the disadvantage of being partly decomposed by albuminous substances.

The time required to saturate the timber depends on its thickness; twenty-four hours are usually allowed for each inch in thickness for boards and small timber; large timber requires from a fortnight to three weeks.

Burnettising.

A solution of 1 lb. of chloride of zinc to 4 gallons of water for timber, and 1 lb. to 5 gallons for canvas, cordage, &c., in a wooden tank. These were the proportions originally specified; 1 lb. of the salt to 9 or 10 gallons of water are now more frequently used.

Timber requires to be immersed for about two days for each inch in thickness, and afterwards taken out and left to dry for about 14 to 90 days.

Canvas, ropes, &c., require to be immersed in the solution for about 48 hours, then taken out and dried.

The process on wood may be more expeditiously performed by forcing the solution into the pores with a pressure of 150 lbs. to the square inch.

The advantage of this process is that it renders the material to which it is applied incombustible.

Payne's Process

is impregnating the wood, while in a vacuum, with a strong solution of sulphate of iron, and afterwards forcing into the timber a solution of sulphate of lime or any of the alkaline carbonates, such as carbonate of soda, by which means the oxide of iron becomes insoluble. The wood is also rendered incombustible by this process.

To Cure Dry Rot in a Building.

Kill the fungus by washing the wood with a strong solution of crude carbolic acid, and the unaffected parts and walls adjoining with a saturated solution of sulphate of iron. The causes of damp should be removed, and the space ventilated.

Wood immersed in Sea Water is liable to the attacks of Pholadidæ and certain species of minute Crustaceæ which are very destructive, viz.:—

TEREDO NAVALIS (*Pholadidæ*), the eggs of which are said to be washed by the sea against the wood, to which they adhere, and after a time, as the minute animal leaves the egg it penetrates the wood, gradually increasing the size of the bore-hole as it grows and advances. This species lines the hole with a shelly substance, but with the exception of the curved valves by which it bores the wood, its body is not so encased. They have been found as long as two feet, and three-quarters of an inch in diameter.

The *Xylophaga* is similar to the teredo, though seldom or never attaining to the same length. It does not line with a shell the cavity which it makes in the wood.

LIMNORIA TEREBRANS (*Asellidæ*).— This is a minute crustacean, seldom exceeding $\frac{1}{6}$ inch in length or $\frac{1}{16}$ inch in diameter. It is found in every part of the world, and will live in the comparatively foul sea water of harbours. It increases rapidly and will attack timber nearly to high water of neap tides, or such portions as are always wet, until the whole of the wood is eaten away. Piles in baulks of unprepared fir timber are destroyed in about three years; beechwood may last a few years longer. The author has known creosoted fir to last not more than from ten to twelve years, even while the wood still strongly smelt of the creosote.

$\frac{1}{12}$

Teredo navalis.

X3

Limnoria terebrans.

X 3

Tanai vitatis.

TANAI VITATIS, although of the same family as the *L. terebrans*, differs from it in appearance. It is about $\frac{1}{5}$th inch in length, and was first discovered by the author as a wood borer in some fender piles in front of Southsea Castle, near Portsmouth. They appear to destroy the wood by tearing its fibres with their powerful claws. They are also furnished with two ciliated fringes near the tail, which appear to be used to keep the water in circulation.

CHELURA TEREBRANS (*Amphipoda*).—These somewhat resemble a boiled shrimp in profile and colour, although very

much smaller. They are about ¼ inch in length, and possess three pairs of swimming feet, a pair of cylindrical false feet, and at the caudal extremity a pair of leaping organs. They attack the wood from the surface similar to the *L. terebrans*. The water in which they live must be perfectly fresh and clear. As in the case of wood attacked by the *L. terebrans*, creosoting will only prolong it by a few years. The author noticed them at work on fir timber which strongly smelt of creosote. They also attack beech.

× 3

Chelura terebrans.

The only, though partial, preservative against any of the foregoing borers is to well creosote the wood, and that which takes up the largest quantity of oil is likely to last longest.

White Ants (*Termites bellicosus*).—One of the most destructive animals to wood in tropical and semi-tropical countries. They consist of king, queen, soldiers, and workers. The former, on emerging from the pupa state, are furnished with wings, which they quickly lose. The queen supplies the colony with eggs to continue the species, at the rate of from ten to twenty thousand per day. Happily there is only one king and queen in a colony, which may contain many thousand workers, with 1 per cent. of soldier ants. However, if the colony is divided into two or more there are certain to be some forms among them capable of being cultivated by the others into reproductive individuals, therefore it is hopeless to attempt to get rid of white ants by destroying the king and queen. The workers are blind, and neutral as regards sex. Their extreme length seldom exceeds ¼ inch. They will destroy the wood on which they feed in a very short time, and there are very few descriptions of timber which are not liable to their attacks. Hitherto teak, greenheart, and the jarrah of Western Australia are the only woods that possess any immunity from their depredations, and they have been known to bore through these to get at the softer woods. Several remedies, such as perchloride of mercury, chloride of zinc, creosote, carbolic acid, arsenic mixed with bone and coal tar, acetate of lead and paraffin have all been tried without success, at the most only to delay the attack for a few months.

Teak is the only wood that has been found uniformly successful, and when this cannot be obtained and the softer woods used, they should be thoroughly creosoted, or if the smell be objected to they should be painted over, particularly at the end grain, with a mixture of arsenic and paraffin or earth oil. A decoction of wild aloes has been found useful against these animals in some countries. All woods should be exposed as

much as possible to light and air. Perchloride of mercury is of little use, as it decomposes in contact with the albumen of the wood, unless a large quantity is used to allow for this.

Deal Standards.

	No.		ft.		in.		in.		ft. sup.		ft. cube.
Petersburg	120	×	12	×	11	×	$1\frac{1}{2}$	=	1320	=	165
London.. ..	120	×	12	×	9	×	3	=	1080	=	270
Quebec (long)	120	×	10	×	11	×	3	=	1100	=	275
„ (short)	100	×	12	×	11	×	$2\frac{1}{2}$	=	1100	=	$229\frac{1}{6}$

Note.—120 deals = 1 hundred.

40	cubic feet of unhewn timber			1 load.
50	„ squared „			
600	superficial ft. of	1 in.	planks or deals	
400	„	$1\frac{1}{2}$	„	
300	„	2	„	
240	„	$2\frac{1}{2}$	„	
200	„	3	„	
170	„	$3\frac{1}{2}$	„	
150	„	4	„	

Battens are 7 in., Deals 9 in., and Planks 11 in. wide.

One square of flooring requires—	No.		ft. in.
For rough floors	$12\frac{1}{4}$	boards	12 × 9
„ ditto ditto, edges shot	$12\frac{1}{2}$	„	„
„ wrought and laid folding ..	13	„	„
„ wrought and laid straight joint	$13\frac{1}{2}$	„	„
„ wrought, ploughed, and tongued	14	„	„
„ rough	16	„	12 × 7
„ edges shot	$16\frac{1}{2}$	„	„
„ wrought and laid folding ..	17	„	„
„ wrought and laid straight joint	18	„	„

Note.—105 superficial feet of prepared flooring boards are usually allowed per square.

Waste in converting timber into scantlings—

White pine logs. . . .	·20	Greenheart	·30
Northern pine	·23	Spanish mahogany . .	·30
Pitch pine	·25	Honduras	·31
Teak	·29	English elm	·34
American white oak .	·30	„ oak	·35

Note.—5 cubic feet per load ($=\frac{1}{10}$th) are usually allowed for waste in sawing fir and pine into planks.

An allowance of *one-third* to *one-half* is usually made for waste on scaffolding, gantries, centering, &c., on reconverting to use.

SHRINKAGE OF TIMBER IN SEASONING.

Planks and boards.	Ultimate shrinkage.
English oak	$\frac{1}{20}$th of the width
Dantzic ,, ...	$\frac{1}{26}$,,
English elm	$\frac{1}{30}$,,
Northern pine	$\frac{1}{32}$,,
American white oak..	$\frac{1}{35}$,,
Cedar, *C. odorata*	$\frac{1}{40}$,,
Larch	$\frac{1}{40}$,
White pine, *P. strobus*	$\frac{1}{46}$,,
White deal, *A. excelsa*	$\frac{1}{70}$,
Teak	$\frac{1}{75}$,,

NOTE.—According to Fincham's experiments, timber from the top of a tree shrinks *less* than that from the butt.

In practice it is usually considered that an ordinary "Northern pine" deal, 9 inches wide, will shrink in seasoning $\frac{1}{4}$ of an inch, and a "white deal" $\frac{1}{8}$th of an inch.

Mr. Laslett gives the following table showing the time required to season timber when under cover:—

	Oak. Months.	Fir. Months.
Pieces above 24 inches square	26	13
Ditto under 24 to 20 inches square ..	22	11
,, 20 to 16 ,, ..	18	9
,, 16 to 12 ,, ..	14	7
,, 12 to 8 ,, ..	10	5
,, 8 to 4 ,, ..	6	3

Planks take about $\frac{1}{2}$ to $\frac{2}{3}$rds the above time, according to thickness. Tredgold gives the time required for seasoning under cover as only $\frac{5}{7}$ths of that in the open.

NAILS REQUIRED FOR FLOORING.

Thickness of Floor.	Length.	Weight per M.		No. to a square.	
		Wrought.	Cut.	Batten widths.	$4\frac{1}{2}$-inch widths.
inches.	inches.	lbs.	lbs.		
$\frac{3}{4}$	2	8	8		
1	$2\frac{1}{2}$	12	12		
$1\frac{1}{4}$	$2\frac{3}{4}$	16	15	340	535
$1\frac{1}{2}$	$3\frac{1}{4}$	25	20		
$1\frac{3}{4}$	$3\frac{1}{2}$	32	27		
2	4	40	35		

NOTE.—267 nails per square are required for floors laid in deal widths, and they should be about $\frac{1}{5}$th heavier than those for floors laid in batten widths.

Force required to extract Nails from White Deal. (Bevan.)

Description of Nail.	No. to a lb.	Length.	Length forced into the Wood.	Force required to Extract.
		inches.	inches.	lbs.
Fine sprigs..	4560	0·44	0·40	22
„	3200	0·53	0·44	37
Threepenny brads	618	1·25	0·50	58
Cast-iron nails	380	1 00	0·50	72
Wrot.-iron sixpenny nails	73	2·50	1·00	187
„ „	..	..	1·50	327
„ „	..	..	2·00	530
„ fivepenny „	139	2·00	1·50	320

Note.—The adhesion of nails increases with the cohesive force of the wood.

Adhesion of Screws.

The following formula, based on Mr. Bevan's experiments, will give approximately the resistance of screws in wood—

$$f = d\,p\,l \times 42{,}000 \text{ for soft wood;}$$
and by 83,000 for hard wood,

d being the diameter of the screw, p the pitch or distance between the threads, l the length in the wood, all in inches, and f the resistance in lbs.

Glue.

The best glue is transparent, and of a clear amber colour, and swells considerably without dissolving when immersed in cold water. Inferior glue dissolves in cold water.

Glue should always be used when fresh boiled, and as hot as possible.

According to Mr. Bevan, cylinders of dry ash, joined end to end with glue, required a force of 715 lbs. to separate them. It was found that the glue did not quite cover the surface of the wood, otherwise it is probable that a greater force would have been required.

The cohesive force of glue in the solid was found to be 4000 lbs. per square inch.

Glue to resist moisture.—Mix 3 oz. of quicklime in 4 oz. of linseed oil, boil until sufficiently thick, spread on tin plates to become hard, when it can afterwards be dissolved over the fire as with ordinary glue. White lead and linseed oil makes a good glue for outside work,

Marine glue is made with indiarubber, 1 part dissolved under gentle heat in 12 parts of mineral naphtha, and when melted, 20 parts of powdered shellac are added, and the mixture poured out on metal plates to cool. (See also p. 74.)

Roofing Felt.

Asphalted felt is frequently used as a covering to the roots of tempopary buildings, for which purpose it is well adapted, and being a good non-conductor of heat it is also used under slates and iron; for the latter, however, dry hair felt is preferable.

Asphalted roofing felt is usually sold in lengths of about 25 to 35 yards by 32 inches wide. The average thickness is $\frac{3}{16}$ths of an inch, and the weight per superficial foot is about 6 to $7\frac{1}{2}$ ounces.

In laying asphalted felt the joints should have a lap of 2 inches, and be nailed at intervals of 2 or $2\frac{1}{2}$ inches with clout nails about $\frac{7}{8}$ of an inch long, weighing about $2\frac{1}{4}$ lbs. per 1000 The nails should be dipped while hot in grease or oil. 1 lb. of nails should be allowed for each square of roofing.

Felt, when laid on boarding, should have a slope of at least 1 in 5; even 1 in 2 would not be too much.

Before laying it is usual to coat the boards and felt with coal tar and whiting mixed, in the proportion of 5 lbs. of the latter to 1 gallon of the former, well boiled together, and applied hot.

Asphalted felt is not capable of itself of withstanding the effects of the weather. It should therefore, immediately after it has been laid, receive at least two coats of coal tar mixed with dry pounded chalk or dead lime, in the proportion of 2 gallons of tar to 6 lbs. of chalk, well boiled together and laid on hot, and while soft sanded over with fine dry sand. This coating should be renewed every two years, or whenever the felt appears to require it.

Sheathing felt is usually made in sheets of 32 in. × 20 in.; the best is formed entirely of hair, and is of the following weights per sheet:

	No. 1	2	3	4	5	
Thickness of sheet	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	inch.
Weight..	16	24	32	40	48	ounces.

The hair felt can be made to adhere to iron by using a cement composed of white-lead 3 parts, red-lead 1 part, whiting 8 parts, mixed with boiled oil until sufficiently diluted to be spread easily on the felt.

Roofing felt can be painted over by giving it a coat of lime-white, then paint with red-lead boiled oil and driers, on which sprinkle fine white silver sand (turpentine should not be used). The felt will then take any colour

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PLASTERER.

The lime used in plastering is chiefly that described as fat lime" on p. 328. When burned, and in lumps, it occupies a space of about $1\frac{1}{2}$ times that of the solid unburned stone, which is again doubled on slaking, making the total increase of bulk about 3 times that of the original stone in the solid

This lime, when mixed with *once* to *twice* its bulk of pit or fresh-water sand, forms the "coarse stuff" used for the under-coats of plastering, with the addition, when used for good work,

of 1 lb. of well-beaten hair to every 2 cubic feet of coarse stuff, and for ordinary work 1 lb. of hair to 3 cubic feet of coarse stuff. The "fine stuff" used for the setting coat of plastering is merely the pure lime slaked, and afterwards saturated with water, which is allowed to evaporate until the lime attains the required consistency.

"Gauged stuff," called "putty and plaster," contains from 3 to 4 parts of plasterer's putty and 1 part of plaster of Paris, which makes it set quickly. For cornices equal parts of putty and plaster are used.

Other materials are also occasionally used, such as plaster of Paris, Keene's cement, Parian cement, Martin's cement, &c. They are, however, more frequently used for mouldings, owing to the rapidity with which they set and the hardness they attain.

MATERIALS REQUIRED FOR PLASTERING.

Per yard super.

Rendering only ($\frac{3}{8}$ inch thick)	Lime (unslaked) ..	·15 cubic foot.
	Sand	·23 "
	Hair	·1 lb.
	Water	1·2 gallon.
Render and set ($\frac{1}{2}$ inch thick)	Lime (unslaked) ..	·22 cubic foot.
	Sand	·23 "
	Hair	·12 lb.
	Water	1·8 gallon.
Render and float ($\frac{5}{8}$ inch thick)	Lime (unslaked) ..	·25 cubic foot.
	Sand	·38 "
	Hair	·17 lb.
	Water	2·0 gallons.
Render, float, and set ($\frac{3}{4}$ inch thick)	Lime (unslaked) ..	·32 cubic foot.
	Sand	·38 "
	Hair	·18 lb.
	Water	2·6 gallon.
Setting with putty and plaster ($\frac{1}{8}$ inch thick)	Lime (unslaked) ..	·10 cubic foot.
	Plaster of Paris	·03 "
	Water	1·00 gallon.

NOTE.—For rubble, or very rough brick walls, the quantities in the above table should be increased.

The first, or "pricking-up" coat, on laths, requires about $\frac{1}{10}$th more coarse stuff than "rendering only."

Superficial Yards of Rendering performed with Portland Cement and Sand.

Proportions.	Thickness in inches.				
	½	⅝	¾	⅞	1
1 bushel cement (nominal)	2·8	2·4	2·1	1·7	1·4
,, and 1 sand . .	4·4	3·8	3·3	2·7	2·2
,, 2 ,, . .	6·4	5·6	4·8	4·0	3·2
,, 3 ,, . .	8·6	7·5	6·4	5·4	4·3
,, 4 ,, . .	10·8	9·7	8·7	7·0	5·4
,, 5 ,, . .	13·4	11·7	10·0	8·3	6·7

Note.—The usual thickness for Portland cement rendering is ¾ of an inch, which should be performed in one operation.

Laths—*Length* = 3 feet and 4 feet.
Width = about 1 inch.
Thickness—
"Single laths" = ⅛ to $\frac{3}{16}$ inch.
"Lath and a half" = $\frac{3}{16}$,, ¼ ,,
"Double laths" = ¼ ,, ⅜ ,,

A bundle contains from 360 to 500 feet run, most frequently the former.

Laths are usually spaced ¼ to ½ inch apart, according to their strength.

A bundle containing 360 feet run (or 400 nominally), nailed with butt joints, will cover about 4½ superficial yards.

Lathing Nails are from ¾ to 1 inch long, according to the thickness of the laths, and are made of wrought or cast iron, the former being always used for oak laths—500 nails are required for a 360-feet bundle of 3-feet laths, and 470 nails for a bundle of 4-feet laths.

Hair.—A bushel of dry hair weighs from 14 to 15 lbs. It is usually classed according to quality, as Nos. 1, 2 and 3; the latter being the best. In the best work 1 lb. of hair is allowed to 2 cubic feet of mortar; the usual quantity is 1 lb. to 3 cubic feet of mortar.

Plaster of Paris (gypsum) is found mainly in the Trias, Tertiary, and Wealden formations; that used in England is

chiefly obtained from Derbyshire and other parts of the country. The best is obtained from Montmartre, in the neighbourhood of Paris. It is also found in Italy, Spain, Switzerland, and in some of the British colonies of North America. The weight per bushel is about 74 lbs.

LIMEWHITING, *once* done, requires 1 cubic foot of slaked lime per 100 super. yards, and $\frac{3}{4}$ lb. tallow.

Ditto, *twice* done, $1\frac{2}{3}$ cubic foot of lime and $1\frac{1}{4}$ lb. tallow.

WHITENING, *once* done, requires 12 lbs. of whiting, $\frac{1}{2}$ lb. of blue-black, indigo, or common ultramarine, and $1\frac{3}{4}$ gallon of ordinary double size, or $1\frac{3}{4}$ lb. of glue for every 100 superficial yards.

Ditto, *twice* done, 21 lbs. of whiting, $\frac{3}{4}$ lb. blue-black, indigo, &c., and $2\frac{3}{4}$ gallons of size.

1 lb. glue will make about a gallon of size.

COLOURING, Stone or Buff—*One coat* requires 10 lbs. of whiting, 3 lbs. ochre, $\frac{1}{2}$ lb. umber, and 2 gallons of single size, per 100 super. yards.

DITTO, French Grey.—*One coat* requires 12 lbs. of whiting, $1\frac{1}{2}$ lb. Prussian blue, and $2\frac{1}{2}$ gallons of single size per 100 super. yards.

NOTE.—Ceilings should be washed previous to whitening with a coarse sponge and cold water.

IRONWORKER.

BOLT HEADS, NUTS, AND WASHERS.

Diameter of bolt = 1.

Diameter of head and nut, square or hexagon = $1\frac{3}{4}$ from side to side.

Diameter of head and nut, hexagon = 2 over the angles.

Thickness of head = $\frac{7}{8}$ of diameter of bolt.

„ nut = 1 „

Washers—

Diam. for iron	= $2\frac{1}{8}$	times	that of bolt.
„ hard wood	= $2\frac{1}{2}$	„	„
„ soft „	= 3	„	„
Thickness for iron	= $\frac{1}{8}$	„	„
„ wood	= $\frac{1}{4}$	„	„

Approximately—the weight of a hexagon HEAD and NUT together equals a rod of iron in length *five* times the diameter of the bolt.

For square heads and nuts it equals *six* times the diameter.

For rose heads and square nuts it equals *four* times the diameter.

RIVETS.

For Steam and Water-tight Joints.

(Fairbairn's Rule.)

The diameter of a rivet for plates less than $\frac{1}{2}$ in. thick } = *Twice* the thickness of the plate.

Ditto for plates $\frac{1}{2}$ in. thick and upwards } = *Once and a half*, ditto.

Length of rivet measured before clenching { Snap heads = thickness of the plates *plus* $2\frac{1}{2}$ times the diam. of the rivet. Countersunk heads = thickness of plate *plus* twice diam. of rivet.

In riveted joints the sum of the sectional areas of the rivets should not be less than the sectional area of the plate for a single shear, or one-half the area of the plate in a double shear, after deducting the rivet holes.

As a general rule, a rivet hole cannot be punched with its edge nearer to that of the plate than its own diameter; to this it is safe to add from $\frac{1}{8}$ to $\frac{1}{4}$ inch, as the plate and rivet get thicker and larger.

The edges of two neighbouring rivet holes should not be placed nearer than from 1 to $1\frac{1}{2}$ diameter, according to the quality of the iron, as there would be a risk of the two holes being punched into one, Drilled holes are safer than punched, as the iron is often injured by the latter.

Pitch of rivets—

$\frac{3}{16}$ in. and $\frac{1}{4}$ in. plates = 6 times thickness of plate.
$\frac{5}{16}$ in. and $\frac{3}{8}$ in. plates = 5 times thickness of plate.
$\frac{1}{2}$ in. and upwards = 4 times thickness of plate.

The pitch in ordinary girder work is about 4 inches from centre to centre.

Lap—*Single riveting*—

	in.	in	in.	in.	in.	in.
Thickness of plate	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{9}{16}$
	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	1.	
Lap..	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$.
	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{5}{8}$	$4\frac{1}{4}$.	

For double riveting add $\frac{2}{3}$rds.

Bridge Riveting—

The resistance of the rivets to shearing is usually taken at 4 tons for wrought iron, and 5 tons for steel per sq. in. of section, and the diam. of the rivet holes should be sufficient to prevent the plate from being slotted by the rivet, calculated for wrought iron at from 5 to 6 tons per sq. in. of the area obtained by multiplying diam. of rivet by thickness of plate. Steel may be taken at 8 tons per sq. in. of bearing area.

SAFE SHEARING STRENGTH OF IRON RIVETS.
(At 4 tons per sq. in.)

Diam. in inches.	Strength in lbs.	Diam. in inches.	Strength in tons.
$\frac{1}{4}$	439	$\frac{5}{8}$	1·227
$\frac{5}{16}$	687	$\frac{11}{16}$	1·485
$\frac{3}{8}$	989	$\frac{3}{4}$	1·767
$\frac{7}{16}$	1347	$\frac{13}{16}$	2·074
$\frac{1}{2}$	1759	$\frac{7}{8}$	2·405
$\frac{9}{16}$	2227	1	3·142

RESISTANCE OF PLATES TO SLOTTING.
(At 5 tons per sq. in.)

Diam. of Rivet Hole.	Thickness of Plate in inches.							
	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$
in.	tons.	tons.	tons.	tons.	tons.	tons.	tons.	tons.
$\frac{3}{8}$	·469	·586	·703	·820	·937	1·055	1·172	1·406
$\frac{7}{16}$	·547	·684	·820	1·045	1·094	1·235	1·367	1·797
$\frac{1}{2}$	·625	·781	·937	1·094	1·25	1·406	1·562	1·875
$\frac{9}{16}$	·703	·879	1·055	1·235	1·406	1·582	1·758	2·109
$\frac{5}{8}$	·781	·977	1·172	1·367	1·562	1·758	1·953	2·344
$\frac{11}{16}$	·859	1·074	1·289	1·504	1·719	1·934	2·148	2·578
$\frac{3}{4}$	·937	1·172	1·406	1·797	1·875	2·109	2·344	2·811
$\frac{13}{16}$	1·016	1·269	1·523	1·777	2·031	2·285	2·539	3·047
$\frac{7}{8}$	1·094	1·367	1·641	1·914	2·125	2·461	2·734	3·281
1	1·25	1·562	1·875	2·125	2·5	2·812	3·125	3·750

NOTE.—Iron rivets are preferred for steel plates, as the heads are not so likely to come off as those of steel; the former should be somewhat larger than for iron plates.

WROUGHT IRON.

Sizes usually Manufactured.

Bar Iron, round or square—
Side or diameter . . . . . . $\frac{1}{4}$ to 3 inches.
Length . . . . 20 to 30 feet.

Bars under $\frac{1}{2}$ inch diameter are classed as rods, and under $\frac{3}{16}$th inch as wire.

Bar Iron, flat—
Section, 1 in. × $\frac{1}{4}$ in. to 6 in. × 1 in.
Length, up to 20 feet.

Plates.—Any thickness from $\frac{1}{8}$ to 1 inch, increasing by 16ths of an inch. Thicknesses less than $\frac{3}{16}$ ths of an inch are classed as "*sheets.*"

Plates may be obtained up to 4 feet wide, 15 feet long, or 30 feet super., at ordinary prices, and sheets up to 3 feet wide and 8 feet long, or 24 feet super.

They are made of larger sizes up to 60 feet super., but at an increased cost. The width is usually limited to 4 feet. *Flitch Plates* are usually kept in stock up to 12 inches wide and $\frac{3}{8}$ inch thick.

Angle and T*-Iron* can be obtained in lengths from 20 to 30 feet up to 12 in. × 3 in. × $\frac{3}{4}$ in. in section, and as small as $\frac{1}{2}$ in. × $\frac{1}{2}$ in. × $\frac{1}{8}$ in. The more common sizes kept in stock are 6 in. × 6 in. × $\frac{7}{8}$ in. and under.

A great variety of other forms can also be obtained in iron and steel.

NOTE.—Most of the foregoing sections can be obtained of larger dimensions, by special order, also in *steel*, but the latter do not run to so large a size as those of wrought iron.

CORRUGATED IRON is usually made in sheets from 6 to 8 feet long, from 2 to 3 feet 2 inches wide before corrugation, and Nos. 16 to 26 S.W. Gauge in thickness. The corrugations are 3 to 6 inches apart from centre to centre, and $\frac{3}{4}$ to $1\frac{1}{4}$ inch in depth.

The usual thickness for roofs is Nos. 18 (=·048 inch) and 20 (=·036 inch) S.W.G.

The sheets when used for roofing should overlap about 6 inches in girth, riveted 9 inches apart, and double riveted at the cross joints.

One-third added to the weight of the sheets measured on the "flat" will give approximately the weight of the corrugated sheets, including laps.

From $2\frac{1}{2}$ to $3\frac{1}{2}$ lbs. of rivets are required for a square of roofing.

In roofs with flat sides the purlins should be about 6 feet apart.

Curved roofs require no trusses, but tie rods about 6 to 8 feet apart when the span is less than 20 feet; the radius of the curve should equal $\frac{2}{3}$rds of the span and the thickness of the iron 20 S.W. Gauge for spans over 12 feet; for smaller spans thinner gauges may be used.

Corrugated and other thin sheets of iron should be galvanised, and when exposed to the sea air, or the sulphurous and other acid vapours of towns and railway stations, it should be painted with oxide of iron or zinc paint in addition. Galvanising sheet iron adds to the weight ·096 lb. per foot super. for each side.

WROUGHT-IRON GIRDERS.

Iron rolled to the required section is generally preferred for the shallow girders used in ordinary building. Rolled girders can be obtained up to

12 or 16 inches in depth and 30 feet in length, or even up to 40 inches deep and 40 feet long if specially ordered. For greater depths built girders must be used; these have webs usually from $\frac{1}{4}$ to $\frac{3}{8}$ inch in thickness in the centre, and from $\frac{3}{8}$ to $\frac{1}{2}$ inch at the ends, with angle irons riveted on each side of the top and bottom edges of the web, which form the flanges.

Where great strength is required, the flanges are thickened by additional plates of iron.

In deep girders the web is sometimes formed with flat bars crossing each other lattice-wise. The stresses on these bars, except when the girder is loaded in the centre only, increase towards the piers, but in small lattice girders it is usual to make the bars of uniform section throughout.

Plate webs are considered more economical in shallow girders than lattice or braced webs.

Steel.

Steel in the shape of girders, roof trusses and pillars, is now more used in building than formerly. It has a much higher tensile and compressive strength than wrought iron, and will stand wear and tear better, as we see on railroads where steel rails are used in preference to those of wrought iron.

Hard steel is fusible, and gives a much higher resistance to compression than cast iron. It cannot, however, be either welded or forged easily.

Mild soft steel, which contains less carbon, is in every way superior, both in strength and ductility, to wrought iron; it can be easily welded or forged.

Steel is very variable in quality as manufactured. The following may be taken as an approximate value of the ultimate strength of soft cast steel when untempered—

Tension and compression = 30 tons per square inch.
Shearing . . . . . . = 24 ,, ,,

Steel can, however, be cast to withstand stresses more than double of these if required, particularly if tempered or hardened.

Cast Iron.

Cast iron has an advantage over wrought iron, as it can be moulded to any shape or section. Its strength in girders, however, cannot be depended upon, owing to its liability to flaws in casting, variableness in the quality of the material, and brittleness. It should therefore only be used to sustain fixed loads, and an excess of dimensions should be allowed beyond those calculated by theory, or in other words, a large "factor of safety" should be adopted.

The strength of cast-iron is improved by remelting if not too often repeated; after being re-melted 10 or 12 times, the strength falls off rapidly.

Cast iron loses strength by heating beyond 120° F., and becomes brittle below 32°.

Cast-iron is usually divided into "grey" and "white." The former is made from foundry pigs containing a large proportion of free carbon, the latter from forge pigs which contain very little free carbon. A mix-

ture of "grey" and "white" is called "mottled" cast-iron. The "grey" may be distinguished from the "white" by treating a fracture with nitric acid, which leaves a black stain on grey iron and a brown stain on white iron.

Properties of Iron.

According to Kirkaldy, wrought iron, when fractured suddenly, presents invariably a crystalline appearance, but when fractured slowly its appearance is invariably fibrous.

Wrought iron is less liable to snap the more it is worked and rolled.

In practice a great variation exists in the strength of iron bars which have been cut and welded. While some are as strong as the uncut bar, the strength of others is reduced fully *one-third*.

Cast iron is more durable than wrought iron; of different qualities of cast iron, the hard white crystalline metal is more durable than the grey or softer kinds.

The comparative liability to oxidation of iron and steel in moist air, according to Mr. Mallet, is:

Cast iron	100
Wrought iron	129
Steel	133

The corrosion of iron is more rapid when partially exposed to wet than when wholly dry, or immersed in water.

Iron in a state of vibration rusts more slowly than when at rest.

Very *thin* iron oxidises more rapidly than *thick* iron, owing to the scales of rust on the former being thrown off as soon as formed, in consequence of the expansion and contraction from alterations of temperature.

Iron is not injured in any way by being galvanised.

PLUMBER, &c.

Lead.

Sheet lead is much used in building for gutters, flashings, linings to cisterns, sinks, and as a covering to flat roofs. It is also used for pipes, fixing ironwork in stone, jointing iron pipes, and for other purposes.

The sheets are either cast or milled (i.e. rolled). They are usually about 6 feet in width and of various thicknesses, seldom, however, exceeding about $\frac{1}{6}$th of an inch. Sheets are cast up to 18 feet in length, and rolled to about 25 feet and by some manufacturers to 30 and 35 feet in length by 6½ and 7½ feet in width.

Owing to the changes which take place in the dimensions of lead from alternations of temperature, it is seldom desirable to lay it in very large sheets, and it should never be so fixed

as to interfere with the expansion and contraction. Solder should therefore not be used when it can be avoided.

Lead does not readily decompose on exposure to the atmosphere, being usually protected by the first coat of oxide which forms on its surface, but it decays rapidly when in contact with Portland cement or lime mortar, wet wood or damp plaster, also by galvanic action when in contact with other metals in the presence of moisture. Pure water, if well aërated and exposed to the atmosphere, quickly corrodes lead. It is also rapidly destroyed by ammonia, acetates, nitrites and nitrates in solution, and by carbonic acid evolved from decaying vegetable matter.

When lead pipes are passed through walls they should be covered with oiled or strong brown paper to protect them from the mortar.

Lead is usually described according to the weight of a superficial foot in lbs. The thicknesses corresponding to given weights will be found in the following table:

THE THICKNESS OF LEAD.

Weight in lbs. per foot superficial.	Thickness in inches.	Weight in lbs. per foot superficial.	Thickness in inches.
1	0·017	7	0·118
2	0·034	8	0·135
3	0·051	9	0·152
4	0·068	10	0 169
5	0·085	11	0·186
6	0·101	12	0·203

The weights recommended are as follows:

Roofs, flats, and main gutters..	7-lb. lead.
Hips, ridges, and small gutters	6 ,,
Flashings	5 ,,
Cisterns and sinks, bottom	7 ,,
,, sides	6 ,,
Soil pipes	8 ,,

Gutters and flats should have a fall of at least 1 inch in 10 feet.

The lead in gutters at the backs of parapets and chimneys should turn up against the wall from 5 to 8 inches, and be covered with a flashing or "apron" of about the same width. Sometimes pieces of lead are used, called "soakers," which

are placed under the slates with a lap similar to that of the slates alongside of walls or parapets against which a portion is turned up under a flashing.

In valley and similar gutters the lead should be turned up under the slates from 7 to 9 inches, according to the pitch of the roof.

The joints of lead in ridges, hips, and flashings, should have a lap of about 4 inches, and in roofs or valleys of about 5 inches.

No sheet of lead should be laid in a greater length than 10 or 12 feet without a drip, roll, or break of some kind to allow of expansion

Drips should not be less than about 2 inches deep, more than 3 inches is unnecessary.

Pipes.

Drawn lead pipes can be obtained from ½ inch to 2½ inches internal diameter, and of any length. Those up to 1 inch diameter are made up in coils 60 feet in length, and those up to 2 inches in coils 30 feet long. Lead pipes are usually described according to the weight per lineal yard, which varies considerably with different manufacturers. (*See* p. 185.)

Zinc.

Zinc, from its lightness, strength, and durability, is a valuable material for covering roofs. When, however, it is impure, or in very thin sheets, it is liable to be acted upon by the atmosphere in places where much coke or coal is burned, also when exposed to the fumes of wood fires. In flats for town houses zinc will seldom last longer than 25 to 35 years, according to the quality and gauge adopted; soot is also very destructive to zinc.

Zinc under ordinary circumstances, like lead, is protected from further corrosion by the first coat of oxide which forms on its surface. Good zinc is of uniform colour, and easily bent without cracking; inferior zinc is blotchy and darker in colour.

Iron or copper should never be placed in contact with zinc when there is the least chance of moisture being present, as they would lead to its rapid destruction. Contact with lime, or water containing calcareous matter, also destroys zinc, but Portland and Roman cement do not appear to be so injurious.

Zinc is usually manufactured in sheets 7 feet by 3 feet, and 8 feet by 3 feet, and if specially ordered it can be obtained up to 10 feet in length. The thickness of zinc is indicated by a special gauge, which varies somewhat with different manufacturers. The old Belgian zinc gauge is as follows:

No.	Approximate S.W. Gauge.	Ounces per sq. ft.	No.	Approximate S.W. Gauge.	Ounces per sq. ft.
8	26	9·00	13	21	19·56
9	25	11·00	14	20	21·56
10	24	13·25	15	19	24·00
11	23	15·50	16	18	26·00
12	22	18·00			

The Vieille Montagne Zinc Mining Company (Braby & Co.) have adopted a new gauge for roofing zinc, as follows:

No.	Thickness in parts of an in.	Ounces per sq. ft.	No.	Thickness in parts of an in.	Ounces per sq. ft.
10	·0180	11·44	15	·0364	21·75
11	·0217	13·30	16	·0400	24·75
12	·0254	15·10	17	·0437	27·69
13	·0290	16·94	18	·0478	30·69
14	·0326	18·75			

NOTE.—The above are only approximate, as slight variations sometimes occur in the weight of sheets of the same nominal gauge. Owing to the fact of there being two gauges for zinc, the approximate weight per sup. foot should always be specified.

The thinnest gauge recommended for roofs by F. Braby & Co., of Euston Road, London, who supply Vieille Montagne Zinc of best quality, is No. 14, but No. 15 or 16 is preferable. When used for gutters, No. 16 gauge should be adopted.

Zinc is affected by change of temperature even more than lead, there is therefore the greater necessity for leaving it quite free to expand and contract. The joints should on no account be soldered.

The slope of zinc roofs should be at least 1 in 15, and the joints across the current should be made with a drip of about 2½ inches to permit the rolls to pass under the projecting upper sheet. If laid with the *drawn roll*, the drip will require to be 3½ inches deep. For gutters a drip of 1½ to 2 inches will be sufficient. If the roof has a fall exceeding 1 in 8 no drips are required, merely a fold at the junction of the sheets.

Drips should be placed about 7½ feet apart, if possible, when more than one, and should not exceed 9½ feet apart.

Zinc should not be laid on oak boarding, which tends to hasten its decay. Deal is preferable, but it should be dry.

Zinc can also be laid on rafters spaced 15 inches from centre to centre, without boarding, by using the Braby system of Italian corrugation.

Where it is absolutely necessary to place iron in contact with zinc it should be galvanised. Iron nails, if used for the boarding under the zinc, should have their heads well punched into the wood, and covered over with a stopping of oil cement or putty.

It is also desirable to avoid all unnecessary contact with lead.

No nails should pass through the outer surface of the sheets or roll caps, as there are various modes of securing them from beneath.

In specifications it is always desirable to state that skilled workmen be employed, and that holding-down slips, improved solid stopped ends and ridge plates (Braby & Co.) be used on flats and sloping roofs.

COPPER.

Copper has been almost entirely superseded by zinc as a roof covering, over which it possesses very few advantages, and is more expensive. It is usually rolled in sheets or plates 4 feet by 2 feet, and in Scotland 4 feet by 3 feet 6 inches, and Nos. 1 to 30 S.W. Gauge, or about 6 oz. to 224 oz. per superficial foot. It is, however, known in the trade by the number of pounds which each plate weighs. The thickness used for roofs and gutters is usually from 12 to 20 oz. per super. foot. The thin sheets are often found with slight cracks or flaws, which if used in roofing would

soon cause it to become leaky. Copper should be fixed in a similar manner to zinc; it should never be soldered. The tensile strength of copper wire is about 16 tons per square inch.

ALUMINIUM.

Aluminium, among the useful metals, is one of the lightest known, as it weighs, when pure, only about 160 lbs. per cubic foot. It is very ductile, can be rolled into sheets of less than $\frac{1}{1000}$th of an inch in thickness, and it can also be drawn into wire or tubes. Under ordinary conditions it is almost incorrodible if pure, as neither carbon dioxide, hydrogen sulphide, or nitric acid has much effect on it in temperatures under 600° Fahr. It is affected less than copper or iron by salt water, but it dissolves in hydrochloric acid.

The ordinary market metal has about the hardness of copper, which is increased by rolling or hammering; it then weighs about 170 lbs. per cubic foot.

The tensile strength of the metal when cast is about 8 tons per square inch, which is also increased by rolling or hammering, provided it is frequently annealed during the process. Sheets, bars, &c., have a tensile strength of about 12 tons per square inch, with a reduction of area of 30 per cent. The tensile strength of aluminium when drawn into wire is higher than when in sheets or bars, and the reduction of area is 45 per cent.

The elastic limit of castings in tension is about 4 tons per square inch, and for bars hammered or rolled it is 7 tons.

The ultimate crushing strength of aluminium when cast into cylinders, of which the length is about $1\frac{1}{2}$ diameters, is somewhat over 5 tons per square inch, although under such conditions the elastic limit is not more than 1 ton per square inch.

Both the tensile and compressive strength of aluminium can be increased by alloying it with copper, nickel or silver.

Its melting point is from 1200° to 1400° Fahr., whereas silver melts at 1830°, copper at 2192°, and lead at 630° Fahr.

The *specific heat* of aluminium is ·2185, and its power of conducting heat is nearly three times that of iron.

The *electrical* conductivity when pure is about one-half that of copper, and $3\frac{3}{4}$ times that of iron. It shrinks in casting about ·26 inch to a foot. Aluminium while being hammered or rolled should be frequently annealed, or it becomes hard, and its ductility diminished.

It is difficult to solder, as none of the ordinary solders will adhere to it. Aluminium can, however, be welded by the usual electrical methods.

The metal has been used by Braby & Co. for roofing tiles to Mansard and other roofs in London. It has also been used in England and America, both in its pure and alloyed state, for various purposes, from a tea-spoon to a ship's boat.

PUMPS.

Suction Pumps, viz. the common hand pump, the lift pump, and the force pump.—The working barrels of suction pumps should be kept within 20 feet of the surface of the water. In HAND PUMPS the stroke is about 9 inches, and the number per minute should not exceed 25. Diam. of suction and delivery pipes are usually $\frac{1}{2}$ that of the working barrel. In LIFT PUMPS for deep wells the stroke = about 12 to 15 inches, diam. of suction pipe, &c. = $\frac{2}{3}$rds that of working barrel. In FORCE or PLUNGER PUMPS diam. of suction pipe = that of plunger. To obtain the working

power add to the weight of the water the frictional resistance of the pipes, also that due to the working parts of the pump and its gearing, usually estimated at ⅓rd of the power applied.

Centrifugal Pumps are chiefly used for drainage and sewage purposes; they require to be worked by horse or steam power. The fan chamber may be placed under the surface of the water, and should not be placed much above it. These pumps are most advantageous for lifts up to 20 ft., and may be worked up to 40 or 50 feet. Their efficiency is about 60 per cent. of the power employed.

Chain Pumps.—These are the best for rough use in drainage or sewage, as they are not liable to become choked. If properly made they may be used for lifts up to 100 feet. Their efficiency = about 60 per cent.

Solders.

For lead—tin, 1 part; lead, 2 parts; fuses at 441° Fahr.
For tin—lead, 1 part; tin, 2; fuses at 340° Fahr.
For pewter—bismuth, 2 parts; lead, 1; tin, 2.
For brass—copper, 1 part; zinc. 1.
For gold—gold, 12 parts; silver, 2; copper, 4.
For silver—silver, 5 parts; brass, 6; zinc, 2.
Hard solder, spelter—copper, 3 parts; zinc, 2.
Soft fine solder=tin, 3 parts; lead, 1.
Very fusible solder—tin, 4 parts; lead, 4; fuses at 320° Fahr.
Ditto, ditto—tin, 1; lead, 1; and bismuth, 2; fuses at 203° Fahr.

Fluxes for Soldering.

Tinned iron—resin or chloride of zinc.
Copper and brass—sal ammoniac or chloride of zinc.
Zinc—chloride of zinc.
Lead—resin.

Note.—Chloride of zinc is made by dissolving zinc in hydrochloric acid.

PAINTER, GLAZIER, &c.

Paint, when mixed with oil, is used in builders' work chiefly for the purpose of preserving or decorating materials, such as iron and wood. The principal ingredient in most colours, except black, is the carbonate of lead known as "white-lead," which is usually ground in oil and sold in casks.

Preparatory to painting woodwork the knots should be "killed," and all holes and defects made good or "stopped" with putty, the latter being performed after the first, or priming coat is applied.

The following proportions of materials are required to paint 100 superficial yards:

Knotting.

Red-lead	·3 lb.
Glue	·3 ,,

Which should be mixed with water and applied hot.

Stopping, &c.

Putty..	4·0 lbs.
Pumice-stone	·5 ,,
Glass-paper	1·0 quire.

1st, or priming coat ..	White-lead	15·00 lbs.
	Red ,, ...	·30 ,,
	Driers (litharge) ..	·30 ,,
	Linseed oil	6·50 pints.
2nd coat	White-lead	12·00 lbs.
	Driers..	·16 ,,
	Linseed oil	2·50 pints.
	Turpentine	·60 ,,
3rd and following coats	White-lead	11·80 lbs.
	Driers..	·15 ,,
	Linseed oil	2·00 pints.
	Turpentine	1·00 ,,
Flatting coat	White-lead	12·00 lbs.
	Turpentine	3·00 pints.

The above form white paint, to which various pigments may be added according to the colour required, reducing the quantity of white-lead in the same proportion.

Raw linseed oil is chiefly used for inside work, and boiled oil for outside work.

The two most common colours for mixed paint are "lead" and "stone." The former being made by adding black, and sometimes a little Prussian blue or indigo, to the foregoing; and the latter by adding burnt umber and spruce ochre, or yellow ochre, ground in oil.

Common black paint seldom contains white-lead, it is usually made with lamp or vegetable black, in the proportion for 100 super. yards of

Black..	12·8 lbs.
Driers (litharge)	·7 ,,
Oil, raw	2·8 pints.
,, boiled.. ..	2·8 ,,

In colouring walls, the quantity of paint absorbed in the first coat depends upon the description of the plaster and degree of smoothness to which it is worked. For ordinary lime,

Portland or Roman cement, which have a considerable degree of porosity, the first coat of paint should be in the proportion of 4 lbs. of white-lead to 1 pint of linseed oil; but for Keene's and other fine cements, which when worked smooth are nearly non-absorbent, the proportions should be $\frac{1}{2}$ pint of oil and $\frac{1}{2}$ pint of turpentine to 5 lbs. of white-lead.

In painting iron, the paint for the first two coats is usually made with red instead of white lead, the latter being said to act chemically on the iron; the same, however, is supposed to occur, but in a lesser degree, with red-lead. Therefore in modern practice paints formed of some of the oxides of iron are preferred. Weight for weight they usually cover a surface about $1\frac{1}{2}$ to $1\frac{3}{4}$ that of white-lead paint, and require for thinning per cwt. of the oxide ground in oil, about $6\frac{1}{2}$ gallons of linseed oil ($\frac{1}{3}$rd boiled and $\frac{2}{3}$rds raw) and 2 gallons of turpentine.

A good paint to preserve iron is coal-tar, distilled to expel the watery vapour and naphtha, and afterwards mixed with turpentine or naphtha and boiled oil, in the proportion of $\frac{1}{2}$ pint of each to a gallon of tar. For work much exposed to the weather slaked lime about $\frac{1}{2}$ lb. to the gallon of tar should be added.

NOTE.—The following results were obtained from experiments made for the author by Mr. J. C. Radford, Surveyor to the Board of Works at Putney:

Materials used in making 1 gallon of paint.

White-lead	20 lbs.	Weight when mixed = 24 lbs. 6 oz.	Surface of wood covered as a priming coat = 113 yards.
Red ,,	6 oz.		
Driers	1 lb.		
Linseed oil	$1\frac{1}{2}$ pt.		
Turpentine	2 ,,		

Materials used in making 1 gallon of stone-coloured paint.

White-lead	21 lbs.	Weight when mixed = 24 lbs. 8 oz.	Surface of wood covered = 127 yards.
Driers	2 ,,		
Burnt umber (ground)	3 oz.		
Linseed oil	$2\frac{1}{2}$ pts.		
Turpentine	$\frac{1}{2}$,,		

Weight of 1 gallon of linseed oil	= 9·35 lbs.
,, ,, spirits of turpentine	= 8·65 ,,
,, ,, coal-tar	= 10·10 ,,
,, ,, pitch	= 10·90 ,,
,, 1 cub. foot white-lead ground in oil	= 252·00 ,,

The surface which a given weight of paint will cover varies with its density and viscidity, also with the nature of the material to which it is applied. For estimates it may be assumed that

1 lb. of white paint mixed with oil, &c., will cover on wood about $4\frac{1}{2}$ super. yards the first coat, $6\frac{1}{2}$ yards the second, and $6\frac{3}{4}$ yards each additional coat.

1 lb. of red-lead paint, mixed and applied as a first coat on iron, will cover about 5¼ superficial yards.

1 lb. of oxide of iron paint, mixed and applied as last, will cover from 8 to 12 superficial yards.

1 gallon of tar, with 1 lb. of pitch included, applied hot, will cover about 12 superficial yards the first coat on wood, and 17 yards each additional coat.

1 lb. of putty for stopping is required for every 20 to 25 yards of surface.

Varnish is used to protect paint from the effects of the atmosphere, and also to give a gloss to the surface.

Varnishes are chiefly made by dissolving one or other of the various resins in either oil, turpentine, or spirits of wine, such as copal, amber, gum anime, for oil varnish; mastic, dammar, or common resin for turpentine varnishes, and gum lac or sandarach for spirit varnishes.

Oil varnish is best for work exposed to the weather, turpentine varnish for indoor work, or spirit varnish when a brilliant polish is required; the latter is, however, more liable to crack than that made with turpentine.

A good and cheap varnish for oak and various indoor work is made by dissolving 3½ lbs. of clear resin in a gallon of oil of turpentine. A pint of varnish will cover with one coat about 14 superficial yards.

French Polish is made by dissolving 1½ lbs. of shellac in a gallon of spirits of wine (cold).

Paper Varnish is made by dissolving 4 lbs. of gum dammar in a gallon of oil of turpentine. The paper should be coated with size, two coats before varnishing.

Size.—The best description is made from glue, about 1 lb. makes a gall. of size. Gold size (oil) is made by mixing ochre with boiled linseed oil, and kept for a few years to season.

Composition of granulated cork to prevent condensation of moisture on surfaces.

For FLOORS covered with asphalte or tar concrete—use red-lead, 1 part to 4 parts of Venetian red thoroughly mixed, sufficient Stockholm tar, and a little turpentine are then added to make the mixture into a *stiff* paste, which is applied with a plasterer's trowel to the thickness of about $\frac{1}{8}$ inch. Cork which has been pulverised into grains about the size of ordinary duck shot, and which can be obtained from the linoleum makers, is then sprinkled over the surface to a depth of about $\frac{3}{8}$ of an inch, and pressed down with a heavy float or beater similar to that used by asphalters. A minimum amount of tar only, to form a stiff paste, should be used, otherwise it will not harden

For covering IRON surfaces, such as girders, iron roofing, &c., the granulated cork is simply pressed into a very thick coating of red or white-lead paint.

For iron surfaces to be lime whited, a wash of finely ground Portland cement laid over the surface with a stock brush may be used.

To remove oil paint from wood.—Take 2 lbs. of washing soda to ½ bushel of quicklime mixed until it attains the consistency of thick cream. spread on the paint and keep moist for one hour. The paint can then be washed off.

Or, dissolve 1 oz. of soft soap and 2 oz. of potash in boiling water. then add 4 oz. of quicklime, the mixture to be applied hot and left for about 12 hours, when the paint can be washed off with hot water.

To paint on zinc.—Dissolve 1 part of chloride of copper, 1 part of nitrate of copper, 1 part of sal ammoniac, in 64 parts of water, then add 1 part of commercial hydrochloric acid. The zinc is to be painted with this mixture and allowed to dry for 24 hours, after which any oil colour will firmly adhere to it.

PAPERHANGER.

To hang 1 dozen yards of paper (21 in. wide) requires:

Flour	½ lb.
Alum	¼ oz.
Boiling water.	

When the paper has to be hung over painted or varnished surfaces, a little powdered resin, about $\frac{1}{16}$ oz. should be added.

A piece of paper is supposed to be 12 yards long and 21 inches wide (20 inches net). French paper is usually 9 yards long and 18 inches wide.

Varnished paper under the name of "sanitary," has been introduced; it will bear washing, if lightly done, with a sponge and cold water, and it can also be cleaned with stiff baker's dough rubbed over the surface.

GLAZIER.

Crown glass.

A crate contains	12	tables of the best.	
,,	15	,,	seconds.
,,	18	,,	thirds.
,,	18	,,	fourths.

The tables measure either 48 or 54 inches diameter. The former yielding about 8½ superficial feet of glass fit for glazing, and the latter about 11½ superficial feet.

Sheet glass may be obtained in four or five qualities, weighing up to 42 oz. per foot super. The stock size of 15 and 42 oz.

glass is 55 in. long, or 38 in. wide, but not to exceed 12 feet in area. Ditto of the 21 and 26 oz. glass is 75 in. long, or 45 in. wide, and 17 feet in area. Ditto of the 36 oz. glass is 65 in. long, or 42 in. wide, and 15 feet in area.

Patent plate.—Best, 2nd, and 3rd qualities may be obtained in thicknesses of $\frac{1}{16}$, $\frac{1}{12}$, $\frac{1}{10}$, and $\frac{1}{9}$ of an inch, and up to 50 in. long, or 42 in wide, and 13 feet in area.

Rough plate (plain or fluted) may be obtained in thicknesses of $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, and $\frac{3}{8}$ of an inch, and up to 100 in. long, or 30 in. wide, and 30 feet in area.

NOTE.—The fluted glass is in two patterns. The small pattern with 11 flutes per inch, and the large with 4 flutes per inch.

Rough plate, cast.—Used for roofs, skylights, &c., may be obtained up to 60 feet in area when the thickness does not exceed $\frac{1}{4}$ to $\frac{3}{4}$ of an inch, and 40 feet area when the thickness is 1 inch.

Polished plate.—Best, second, and silvering qualities can be obtained up to 100 feet in area. The glazing qualities are usually $\frac{3}{16}$, $\frac{1}{4}$, and $\frac{3}{8}$ inch in thickness.

NOTE.—Greater thicknesses and sizes can be obtained at special rates.

Glass $\frac{1}{10}$th of an inch in thickness weighs about 21 oz per superficial foot.

To remove old putty.—Paint the dry putty with nitric or hydrochloric acid, and after about an hour it will have become soft enough to be easily removed; or, apply a hot iron, by which it will become soft enough to remove immediately.

CONVENTIONAL COLOURS USED FOR DRAWINGS.

EARTHWORK	Plan	Burnt umber.
	,, turfed	Hooker's green.
CONCRETE	Neutral tint, mottled.	
BRICKWORK	Elevation	Lake, with yellow ochre.
	Plan	Indian red, or lake.
STONEWORK	Elevation and Plan.	Light sepia or Indian ink; and for granite a wash of Venetian red and indigo, according to colour, dotted black with a pen.
SLATE	Prussian blue and sepia.	
WOODWORK	Pine or fir	Gamboge and burnt sienna.
	Oak	Gamboge and sepia.
	Mahogany	Lake and sepia.
CAST IRON	Indian ink and indigo with lake.	
WROUGHT IRON	Prussian blue.	
STEEL	Lake and indigo.	
LEAD	Cobalt and Indian ink.	
BRASS	Gamboge.	
COPPER	Lake with Venetian red.	
GLASS	Neutral tint and lake.	

NOTE.—Sections to be the same colour as the plan, but darker.

RECEIPTS USEFUL TO BUILDERS.

CAST-IRON *surface, to harden.*—Heat the iron to a deep red, and dip into a mixture consisting of water, 1½ gallons, sulphuric acid, ¼ pint, and nitrate of potassium (*saltpetre*), 1 oz.

CASTINGS, *to anneal or soften.*—Place the castings, surrounded by sawdust, in an iron box closed up with clay to exclude the air, and keep it at a red heat for several hours. Then allow them to cool gradually, and do not withdraw until cold.

CAST STEEL *to weld.*—Heat the steel and apply to the weld powdered borax mixed with about $\frac{1}{10}$th part of salammoniac (chloride of ammonium), taking care not to make the steel too hot or it will crack under the hammer.

CEMENTS, *for aquariums, &c.*—Boiled oil, litharge and red-lead mixed in equal proportions, also a slightly larger proportion of white-lead than red-lead.

Another composition which dries more quickly is made with equal portions of plaster of Paris, litharge, fine white sand, and about $\frac{1}{3}$rd of a portion of finely-powdered resin. When required for use mix a small quantity at a time with boiled oil and ordinary dryers, so as to be of the consistence of glazier's putty.

A slower setting cement is made with gold size, red-lead, litharge, and silver sand mixed into a thick paste.

For filling cracks in wood.—1 part glue dissolved in 6 parts of water, afterwards mix sawdust and finely prepared chalk, or if required to withstand wet, use equal parts of white- and red-lead, litharge, and finely-prepared chalk mixed to the proper consistence with oil varnish.

To join broken stone.—Fine clean river sand 20 parts by weight, litharge 2 parts, quicklime 1 part, all made into a paste with boiled linseed oil.

Brune's composition for repairing stone, as used in Paris.—Oxide of zinc, 2 parts by weight, pounded limestone and grit, of each 2 parts. These should be mixed together and ground into a powder, and afterwards made into a paste with a saturated solution of chloride of zinc (i e. zinc dissolved in hydrochloric acid) adding chloride of ammonium, equal to about $\frac{1}{6}$th part of the zinc in the chloride of zinc. Dilute with $\frac{2}{3}$rd of its bulk of water.

NOTE.—2½ pints of the liquid to 1 lb. of the powder are required to form a paste.

To attach glass (as in lamps) to brass mountings.—Boil resin 3 parts, with caustic soda 1 part, and water 5 parts. Mix with about one-half of its weight of plaster of Paris.

To attach brass or other metal letters to glass.—Mix litharge, 2 parts, white lead, 1 part, boiled oil, 3 parts, and gum copal, 1 part. This dries quickly.

To fill cracks in stucco work, &c.—Mix Parian cement with gold size to a stiff paste, and add a little white-lead.

Perfectly dry whiting for common work may be substituted for the Parian cement.

For rust joints in iron (quick setting).—Fine clean iron borings 5 lbs., flowers of sulphur 2 ozs., powdered chloride of ammonium (salammoniac) 1 oz. Made into a paste with water.

Ditto, ditto (slow setting).—Fine iron borings 12 lbs., flowers of sulphur 1 oz., chloride of ammonium 2 ozs. Made into a paste with water as before.

To repair cracks in iron pots and other vessels.—Melt 2 parts sulphur, and add 1 part fine black lead; pour out on a metal slab, and when required melt and apply with a hot soldering iron.

Ditto for iron tanks.—50 parts by weight of iron borings, and mix with 1 part of chloride of ammonium (salammoniac) in water to form a paste.

For leaks in zinc or galvanised iron roofs.—White-lead, some white sand, and dry pipe-clay, equal parts of each, made into a paste with boiled linseed oil.

To enable Portland cement to stand heat in furnace work.—Mix with common salt in the proportion of 5 of salt to 6 of cement, and use as ordinary mortar.

Copper Pipes, *to bend.*—Fill with resin or lead, and after bending melt out the filling.

Marine *Glue.*—Dissolve by gentle heat 1 oz. of india-rubber in half a pint of mineral naphtha, after which add 4 oz. of powdered shellac, again apply gentle heat and pour out on a metal plate to cool. For use, re-melt and apply with a brush.

The india-rubber is easily dissolved cold in pure benzine, heat would be dangerous, as benzine is explosive at a low temperature.

Glue *to resist moisture.*—Mix 1 pint of skimmed milk with 4 oz. of ordinary glue, or—(see also p. 353).

Quicklime boiled with linseed oil to the consistency of

treacle; when cold it can be dissolved by heat similar to ordinary glue. (See p. 353.)

MAP VARNISH.—Dissolve Canada balsam in spirits of turpentine by placing the bottle in warm water. Allow it to stand for several days in a warm place to settle. Before using give the map a coat of a thin solution of clear glue.

MARBLE CHIMNEY-PIECES, *to clean from smoke stains.*—Rub with a clean soft rag dipped in benzole, or apply a paste of chloride of lime, and let it remain for 24 hours.

ORDINARY STAINS *in marble* may be removed with finely powdered chalk or whiting, 1 part, pumice stone, 1 part, carbonate of soda, 2 parts, mixed with water and rubbed over the surface, which must afterwards be washed with soap and water.

PAINT *to stand hot water.*—Clean the metal with turpentine or benzine, and apply a mixture of white-lead, carriage varnish, and spirits of turpentine in two coats; afterwards give a thick coat of white-lead and carriage varnish as quickly as possible.

FLEXIBLE PAINT *for canvas, &c.*—Mix while hot about 12 lbs. of ordinary paint with 4 oz. of yellow soap dissolved in 1¼ pints of boiling water.

PARCHMENT, *to colour on, such as deeds, leases, &c.*—After the outline of the map is inked in, cover the whole with a saturated solution of alum in water. When dry, brush off the undissolved alum, after which the parchment will easily take the colour.

To remove iron screws when rusted.—Scrape the rust off the head and drop some parafin oil over it. After soaking into the wood, the screw may easily be drawn in the usual manner, or take a red hot poker and heat the screw by placing the point on the head.

Springs and locks may also be cleaned by parafin oil.

Dipping screws in grease will enable them to be driven into hard wood more easily.

WHITEWASH *for outside work.*—Slake half a bushel of lime in a large pail, add 1 lb. of common salt, ¼ lb. of sulphate of zinc, and 1 gallon of fresh milk.

CONSTANTS OF LABOUR.

The value of Builders' Work depends upon—

1. The Cost of Materials.
2. " Labour.
3. General and Incidental Expenses.
4. Profit.

THE PRICE OF MATERIALS is regulated by the natural law of Supply and Demand, and should include an allowance for waste and carriage.

THE COST OF LABOUR is dependent on the wages of the workman, which include the use of certain tools, and the amount of work he will perform in a given time, termed the CONSTANT OF LABOUR.

THE GENERAL AND INCIDENTAL EXPENSES OF A WORK include the use and waste of plant, erection and removal of offices, storehouses, sheds and workshops, if required, superintendence and setting out the work, surveyor's charges for preparing the bills of quantities and measuring up extras and omissions, fees and requirements of local authorities, and other expenses not included in the items of the work, also the interest on the capital advanced in the purchase of materials and payment of wages.

PROFIT is the sum by which the builder is remunerated for his personal attention and skill. This, when made to include the risk arising from fluctuations in the prices of labour and materials during his contract, and the interest upon the capital advanced, although a part of the general expenses, is usually estimated at 10 per cent. on the value of all the other items.

The only portion of the foregoing within the limits of the present work is that relating to the Constants of Labour, as follows:

The time during each day which the workman is assumed to be at work is 10 *hours.*

EXCAVATORS' WORK.

Excavating only—per cubic yard.	Hours of a Labourer or Navvy.
Vegetable earth	·45
Loam (sand and clay mixed)	·60
Clay	1·00
Earth mixed with coarse gravel, &c. ..	1·50
Chalk	2·00
Rock requiring blasting	4·50

In narrow trenches for foundations, drains, &c., add one-third to the above.

	Hours of a Labourer or Navvy.
Throwing with a shovel to a height of 5 feet, or filling trucks—per cubic yard.	
Vegetable earth, loam, or sand	·46
Hard earth, clay, &c.	·55
Mud in a wet state	·65
Filling barrows—per cubic yard.	
Vegetable earth, loam, or sand	·45
Clay, stony earth, &c.	·52
Mud in a wet state	·56
Removing 25 yards with wheelbarrows, depositing and returning—per cubic yard.	
Vegetable earth or loam	·26
Clay, stony earth, sand, or mud	·30
Levelling earth, &c., from barrow heaps, without throwing—per cubic yard.	
Vegetable earth, sand, loam, &c.	·12
Clay, stony earth, &c.	·19
Trimming slopes of cuttings—per superficial yard.	
Vegetable earth, sand, loam, &c.	·15
Clay, stony earth, &c.	·20
Levelling and trimming slopes of embankments—per superficial yard.	
Vegetable earth, loam, &c.	·10
Clay, stony earth, &c.	·14
Filling at backs of walls, &c.—per cubic yard.	
Vegetable earth, loam, or sand	·48
Clay, stony earth, &c.	·55
Mud (wet)	·58
Ramming earth—per cubic yard.	
Vegetable earth, loam, or sand, in layers 6 inches thick	·40
Ditto, ditto, in layers 12 inches thick	·25
Clay, stony earth, &c., in layers 6 inches thick	·48
Ditto, ditto, in layers 12 inches thick	·29

	Hours of a Labourer or Navvy.
Clay puddle—per cubic yard.	
Tempering and spreading in layers 9 inches thick	6·50
Ditto, ditto, in layers 12 inches thick ..	5·50
Turf about 3 in. thick—per superficial yard.	
Cutting and stacking, without removal ..	·30
Re-sodding	·58

The labour of filling turf into barrows and removing may be taken the same as for vegetable earth.

Removing 220 yards lineal, depositing the load and returning—per cubic yard.	Hours of a Driver, Horse and Cart.
Vegetable earth or loam	·39
Clay, stony earth, &c...	·45

This includes the time lost while the cart, which contains 1 cubic yard, is being filled by two men assisted by the driver.

Removing 220 yards, depositing the load and returning, when the horse is not detained at the cutting—per cubic yard.	
Vegetable earth, &c.	·19
Clay, stony earth, &c...	·22
Removing each additional 220 yards and returning—per cubic yard.	
Vegetable earth, &c.	·12
Clay, stony earth, &c...	·14

NOTE.—When a load is removed up an inclined plane not exceeding 1 in 10 the *extra* labour entailed is equivalent to removing the same load on a horizontal plane, the length of which equals the rise multiplied by the reciprocal of the fraction which represents the coefficient of friction.

In practice it is usual to add for inclined roads 3 yards to the horizontal length for every foot of rise, and to consider them as if they were level.

The vertical transport of earth has been found by experiment to equal 24 times the labour of moving the same distance on a horizontal plane when barrows are used, and 14 times when horses and carts are used.

BRICKLAYERS' WORK.

		Hours of a Ground Labourer.
Mixing concrete, wheeling, depositing and ramming, &c.	*per cub. yd.*	2·30

As follows:

Measuring the materials	·4
Turning over twice	·6
Filling into barrows	·5
Wheeling, say 25 yards	·3
Levelling in layers	·2
Ramming	·3
Total	2·3

Making mortar by hand		7·20

NOTE.—A two-horse pug mill mixes about 25 yards of mortar *per day*.

Picking up and stacking bricks without moving	*per thousand*	2·00
Ditto, ditto, if handed to him ..	"	1·50
Selecting bricks for facings ..	"	3·00
Taking down old brickwork laid in mortar, cleaning and stacking the bricks	*per rod*	40·00

		Hours of a Bricklayer and Labourer.
Brickwork in mortar, worked fair both sides, exclusive of pointing, to walls 1 brick thick	*per rod*	51·32
Ditto, ditto, 1½ brick thick	"	45·00
" " 2 "	"	43·16
" " 3 "	"	41·44
" " 4 "	"	39·08
" " in covering arches, 1½ brick thick and upwards	"	40·90
Add to any of the foregoing, if in Portland cement		3·00
Ditto, to ovens and coppers ..	*per cub. yd.*	4·80
Rough axed arches over openings	*per sup. ft.*	·35
Add, if elliptical	"	·20
Add, if pointed with mortar ..	"	·15
Gauged arches, rubbed only ..	"	·80
Ditto, cut, rubbed, and set in putty	"	1·20
Add, if elliptical	"	·03
Pointing new work, flat joint in mortar, including raking out the joints	*per sup. yd.*	·90

		Hours of a Bricklayer and Labourer.
Pointing new work, flat joint, in cement, and raking out mortar joints	*per sup. yd.*	1·10
Add for raking out mortar joints in old work	,,	·10
Add, for raking out cement joints	,,	·50
Add, if worked from a scaffold, including erecting and removing	,,	·25
Pointing, tuck, in mortar, including raking out the joints	,,	2·50
Ditto, ditto, in cement	,,	2·58
Bricknogging, set flat in mortar	,,	·80
Ditto, on edge in mortar	,,	·60
Paving with stock bricks laid flat in sand	,,	·43
,, on edge in sand ..	,,	·65
,, laid flat in mortar	,,	·70
,, on edge ,,	,,	·86
,, laid flat in cement	,,	·80
,, on edge ,,	,,	1·00
Ditto, with paving bricks laid flat in sand	,,	·40
,, on edge in sand ..	,,	1·04
,, laid flat in mortar	,,	·80
,, on edge ,,	,,	1·20
Tiling, plain; 3 inch weather	*per* 100 *sup. ft.*	7·40
,, ,, 3½ inch ,,	,,	7·20
,, ,, 4 inch ,,	,,	7·00
,, pan, laid dry	,,	4·00
Add to pantiling, if pointed outside	,,	2·40
3 inch drain pipes, laying and joining in cement	*per lineal foot*	·08
4 inch ditto, ditto	,,	·11
6 inch ,, ,, ...	,,	·16
9 inch ,, ,, ...	,,	·23
12 inch ,, ,, ...	,,	·31
15 inch ,, ,, ...	,,	·40
18 inch ,, ,, ...	,,	·50
Sash and door frames, bedded and pointed	*each*	·75
Chimney pots, 1st size, set in mortar	,,	·98
Ditto, 2nd size, set in mortar ..	,,	·80
Ditto, 3rd size, ,, ..	,,	·65

		Hours of a Bricklayer and Labourer.
Add to chimney pots, if set in cement	*each*	·20
		Hours of a Bricklayer only.
Working each fair face to brickwork in mortar, including striking the joints	*per sup. ft.*	·07
Ditto, ditto, in cement	,,	·09
Add for malm or other facings of superior bricks	,,	·06
Add for circular face worked to template	,,	·05
Rough cutting to brickwork ..	,,	·15
Fair ditto	,,	·40
Cutting to groin points (the first ring)	*per lineal foot*	1·00
Rough birdsmouth cutting on brickwork..	,,	·20
Fair ditto	,,	·28
Cutting a rebate, 3 inches girth, fair in ditto	,,	·22
Cutting holes in brickwork not exceeding 4 in. × 3 in., and pinning ends of timbers, &c. ..	*each*	·55
Bedding and pointing ordinary window frames about 4 ft. × 7 ft.	,,	1·00

Add to pantiling, if pointed inside	*per square*	1·50

MASONS' WORK.

Rubble stone—per cubic yard.	Hours of a Labourer.
Filling barrows	·60
Removing 25 yards and returning with the empty barrow	·40
Unloading barrows	·30
Taking down old masonry built with mortar, cleaning and stacking the stone	6·00

Rubble masonry—per cubic yard.	Hours of a Mason and Labourer.
Built dry in courses to foundations, &c. ..	2·40
,, with mortar to ditto	2·80
,, ditto, above ditto..	3·10
,, ditto, when all the beds are horizontal	4·80
Add, if built with cement	·90

		Hours of a Mason and Labourer.
Ashlar masonry—per cubic foot.		
Rough facing averaging 12 inches thick to rubble work, with chisel drafted margins built in courses 12 inches high..		·80
		Hours of a Mason only
Add to rubble masonry for each fair face	*per sup. ft.*	·10
Add to last, if hammer dressed ..	,,	·20
,, ,, if curved	,,	·46

PURBECK STONE.

Plain work, tooled..	*per sup. ft.*	1·30
,, circular	,,	1·75
Sunk work, tooled	,,	1·60
,, circular	,,	2·00

LABOUR ON PORTLAND STONE, &c. (IN POSITION).

Description of Labour.	Time of a Mason or Stonecutter, per superficial foot.		
	Caén.	Bath.	Portland.
	hours.	hours.	hours.
Sawing (whole)	·10	·09	·60
Plain work, tooled	·50	·45	1·10
,, rubbed	·62	·56	1·25
,, tooled, circular ..	·90	·84	1·55
Sunk work, rough	·75	·68	1·20
,, ,, circular ..	·95	·90	1·45
,, tooled	·92	·85	1·50
,, rubbed	1·00	·92	1·63
,, ,, circular ..	1·15	1·05	1·75
Moulded work, rubbed	1·55	1·50	2·00
,, ,, circular	2·00	1·90	3·00
,, Gothic ,, ...	2·40	2·30	4·00
,, ,, ,, circular	3·18	3·00	5·30
Spherical work, plain	2·55	2·40	4·20
,, ,, rubbed	2·85	2·65	4·70

NOTE.—Work done on the banker takes about one-third less labour than the above.

Yorkshire Stone.

		Hours of a Mason.
Whole sawing	per sup. ft.	·80
Rough face	,,	·80
,, sunk work..	,,	1·40
Add for each tooled face	,,	·70
,, ,, rubbed face	,,	·80
,, ,, circular ,, ...	,,	·55
Moulded work, plain tooled ..	,,	3·00
Add, if circular	,,	1·00
,, if rubbed	,,	·85

Labour on Granite.

Description of Labour.	Time of a Mason, per superficial foot.	
	Cornish.	Aberdeen.
	hours.	hours.
Plain face, roughly axed	1·25	1·46
,, ,, circular..	1·55	1·75
,, fine axed	1·75	2·00
,, ,, circular	2·15	2·40
Sunk work, roughly axed	1·90	2·15
,, ,, circular..	2·40	2·65
,, fine axed	2·35	2·70
,, ,, circular.. ..	2·90	3·25
Moulded work..	3·80	4·25
,, circular	5·00	5·45

Labour on Marble.

Description of Labour, including Sawing and Polishing.	The Time of a Mason, per superficial foot.	
	Statuary, or Veined.	Kilkenny, or Black.
	hours.	hours.
Plain work	6·60	8·00
,, circular	8·60	10·00
Sunk work	12·20	15·05
,, circular	18·00	20·80
Moulded work	18·00	20·80
,, circular	26·10	28·80

		Hours of a Mason and Labourer.
Taking up 2 and 2½ inch paving and stacking near the site ..	per sup. ft.	·06
Ditto 3 and 4 inch, and ditto ..	„	·08

Granite or other pitcher paving in courses averaging 6 inches laid in gravel.

		Hours of a Pavior and Labourer.
6 inches deep	per sup. yd.	·76
7 „	„	·80
8 „	„	·84
9 „	„	·87
Add, if grouted with thin mortar	„	·16
Add, if grouted and set with mortar	„	·35
Pebble paving laid in gravel ..	„	·50

		Hours of a Mason and Labourer.
Cube stone, hoisted and set in mortar	per cub. ft.	·28
Ditto, hoisted and set in cement	„	·35
Add, when in scantling lengths or larger sizes	„	·10

Yorkshire or other paving, setting only in mortar.

2 inch	per sup. ft.	·07
2½ „	„	·08
3 „	„	·09
4 „	„	·11

The labour of squaring flags for paving varies from ·08 to ·12 hours of a mason per foot superficial for 2 and 2½ inch, and from ·12 to ·15 hours for 3 and 4 inch, according to the size of each flag.

		Hours of a Labourer.
Breaking stones to a size that will pass through a ring 1½ inch in diameter	per cub. yd.	7·00

This constant has been obtained from experiments on limestones and stones somewhat harder than Purbeck; but for granite and very hard silicious stones it should be increased by about one-third.

Spreading broken stones as for metalling roads, in thickness of 3 inches..	per sup. yd.	·22

		Hours of a Slate Mason.
Planing slate slabs	per sup. ft.	·16
Polishing ditto with sand	„	·25
Ditto, with very fine sand, or rubbing	„	·30
Filing square to edges of slate slabs.		
½ inch thick	per lineal ft.	·13
¾ „	„	·16
1 „	„	·21
1¼ „	„	·24
1½ „	„	·28
2 „	„	·40
Rounded nosings to slate slabs.		
½ inch thick	„	·24
¾ „	„	·30
1 „	„	·36
1¼ „	„	·41
1½ „	„	·46
2 „	„	·50
Grooving for zinc or iron tongued joints, each groove	„	·16
Ditto, for slate tongue	„	·22

SLATERS' WORK.

Description of Slate.	The time of a Slater and Boy per square.	
	Laying only.	Preparing and laying.
	hours.	hours.
Doubles (2 nails each) ..	2·50	3·90
Ladies „ ..	1·50	2·60
Countesses „ ..	1·10	1·90
Duchesses „ ..	1·00	1·55
Queens (average size)	0·70	1·30

		Hours of a Slater and Labourer.
Plastering (torching) against under side of slating	per sup. yd.	·50

CARPENTERS' WORK.

Sawing Timber.		Hours of a Pair of Sawyers.
Pine, Baltic	*per sup. ft.*	·025
„ American	„	·022
„ Pitch	„	·040
Oak, English	„	·045
„ Baltic or American	„	·038
Ash, beech, or birch	„	·034
Elm	„	·033
Teak	„	·050
Mahogany, Honduras	„	·033

Add two-thirds to any of the above if sawn arriswise.

NOTE.—The timber in the following tables is supposed to be supplied to the carpenter in scantlings of convenient size.

	Hours of a Carpenter.
To work one cubic foot of Northern Pine into plates, bond timbers, ground joists, &c., when	
16 square inches in section and under	·60
36 „ „ „	·53
81 „ „ „	·46
Over ditto „ „	·40
Ditto, ditto, into rafters, purlins, ceilings, joists, &c., when	
16 square inches in section and under	·80
36 „ „ „	·69
81 „ „ „	·61
Over ditto „ „	·54
Ditto, ditto, into rough frames, as in naked floors, &c., when the section is not less than 16 square inches	1·00
Ditto, ditto, into trusses, &c., when the section is not less than 16 *square inches*	1·35

NOTE.—With heavy timber the assistance of a labourer is required for every two or three carpenters, according to the size of the scantlings and class of work.

Labour on Northern Pine Timber.

Description and Scantling.	The time of a Carpenter—per cubic foot.				
	Rough.	Wrought 1 side.	Wrought 2 sides.	Wrought 3 sides.	Wrought all round
Framed and fixed—	hours.	hours.	hours.	hours.	hours.
Under 16 square inches in section	1·60	2·08	2·32	2·56	2·80
„ 36 „ „	1·38	1·74	1·92	2·10	2·28
„ 81 „ „	1·22	1·50	1·64	1·78	1·92
Over 81 „ „	1·08	1·28	1·38	1·48	1·58
Add, if diminished	·60	·65	·70	·75	·80

Curved work usually takes one-half more labour than straight.

The labour on oak may be taken at $1\frac{1}{3}$ of the above for large, and $1\frac{1}{2}$ times for very small timbers.

		Hours of a Carpenter.
Planing Northern Pine	*per sup. ft.*	·13
„ including squaring ..	„	·17
Sawing off the heads of pine piles with a handsaw	„	·30
Ditto, ditto, oak ditto	„	·60
„ the ends of sheeting piles or planking ditto	*each*	·10
Holes averaging ¾ inch diameter bored through pine for bolts, &c.	*per lineal ft.*	·20
Ditto, ditto, through oak	„	·30
Forming a single tenon, including the mortise to pine posts.		
Under 16 square inches in section	*each*	·40
„ 36 „ „	„	·60
„ 81 „ „	„	·80
„ 144 „ „	„	1·00
Forming a double tenon, including the mortise to pine posts.		
Under 16 square inches in section	„	·60
„ 36 „ „	„	·90
„ 81 „ „	„	1·20
„ 144 „ „	„	1·50

CENTERING.

Description.	Time of a Carpenter	Time of a Labourer.
	hours.	hours.
For plain cylindrical vaults or arches .. .. *per square*	15·50	7·50
„ groined arches .. .. „	32·00	10·00
„ skew ditto .. .. .. „	17·00	8·00
„ drain sewers, &c. .. *per sup. ft.*	·22	—
„ coach-head trimmer arches .. .. .. „	·55	—

		Hours of a Carpenter.
Turning piece to 4½ inch soffit ..	*per lineal ft.*	·18
Extra to groin points in centering	„	1·00

DEALS FIXED COMPLETE—*per superficial foot.*

Thickness.	The time of a Carpenter.					
	Rough.	Edges short.	Wrought one side and edges.	Wrought both sides and edges.	Wrought one side and framed.	Wrought both sides and framed.
In widths of 6 in. and upwards in unframed work, or over 4 superficial feet in framed work—	hours.	hours.	hours.	hours.	hours.	hours.
½ inch	·051	·084	·170	·230	·347	·417
¾ „	·060	·100	·187	·247	·360	·430
1 „	·069	·117	·204	·264	·380	·470
1¼ „	·079	·137	·228	·291	·400	·512
1½ „	·090	·157	·251	·317	·427	·550
2 „	·110	·196	·298	·370	·589	·711
2½ „	·130	·237	·345	·423	·668	·801
3 „	·151	·278	·392	·476	·746	·890
In widths of less than 6 in. in unframed work, or under 4 superficial feet in framed work—						
½ inch	·070	·120	·226	·286	·417	·487
¾ „	·082	·143	·249	·309	·435	·505
1 „	·094	·166	·272	·332	·460	·550
1¼ „	·106	·191	·301	·364	·485	·597
1½ „	·118	·217	·331	·397	·517	·640
2 „	·140	·267	·389	·461	·689	·811
2½ „	·163	·295	·448	·526	—	—
3 „	·284	·345	·506	·590	—	—

FLOORS OF DEAL LAID AND CLEANED OFF ONLY—STRAIGHT JOINT, *per square.*

Thickness.	Time of a Carpenter.					
	In Deal Widths.			In Batten Widths.		
	Rough and edges shot.	Wrought, edges shot, and fillistered.	Wrought, rebated, and filleted.	Rough and edges shot.	Wrought, edges shot, and fillistered.	Wrought, rebated, and filleted.
	hours.	hours.	hours.	hours.	hours.	hours.
¾	2·20	3·00	—	2·98	3·93	—
1	2·38	3·18	—	3·23	4·18	—
1¼	2·62	3·42	4·26	3·55	4·50	5·60
1½	2·90	3·70	4·56	3·92	4·87	6·00
2	3·40	4·20	5·13	4·57	5·52	6·75
2½	3·85	4·65	5·66	5·17	6·12	7·45
3	4·26	5·07	6·16	5·72	6·67	8·10

For FLOORS laid in half-board widths add *one-half* to the Constants for Battens.

NOTE.—The labour of laying FOLDING FLOORS is very little less than that of laying straight-joint floors, which are now pressed together by means of a cramp made for the purpose.

FLOORS OF DEAL PREPARED FROM BOARDS SAWED TO THICKNESS AND LAID COMPLETE, WITH STRAIGHT JOINTS AND TONGUED HEADINGS—*per square.*

Thickness.	The Time of a Carpenter.			
	In Deal Widths.		In Batten Widths.	
	Wrought.	Wrought. rebated, and filleted.	Wrought.	Wrought, rebated, and filleted.
	hours.	hours.	hours.	hours.
¾ inch ..	6·38	9·68	7·08	—
1 „ ..	7·18	10·93	7·98	—
1¼ „ ..	8·06	12·28	8·97	12·83
1½ „ ..	8·98	13·25	10·05	14·13
2 „ ..	10·80	14·40	12·10	16·90
2½ „ ..	12·60	16·50	14·20	19·35
3 „ ..	14 40	18·40	16 30	21·65

FLOORS OF ENGLISH OAK PREPARED AS LAST AND LAID COMPLETE, WITH STRAIGHT JOINTS IN 7-INCH WIDTHS—*per square.*

Thickness.	The Time of a Carpenter.			
	Rough edges shot and fillistered.	Wrought edges shot and fillistered.	Wrought, rebated, and filleted, or ploughed and tongued.	Add if Oak Trenails are used instead of Nails.
	hours.	hours.	hours.	hours.
1 inch ..	10·94	17·60	—	—
1¼ „ ..	12·70	19·60	28·87	6·00
1½ „ ..	14·54	21·74	30·00	7·00
2 „ ..	18 27	26·00	33·34	9·50
2½ „ ..	21·87	30·00	38·34	12·00

Doors and Gates of Deal, Ledged—*per superficial foot.*

Thickness.	The Time of a Carpenter.							
	Rough, and edges shot.	Add if braced.	Wrought.	Wrought, ploughed, and tongued, or rebated.	Add if braced.	Add if hung.		
						In one leaf.	In two leaves.	In two heights.
	hours.	hours.	hours.	hours.	hours.	hours.	hours.	hours.
¾ inch ..	·17	·04	·33	·38	·08	·10	·13	·15
1 " ..	·19	·05	·35	·42	·08	·12	·16	·18
1¼ " ..	·22	·05	·39	·47	·09	·14	·18	·21
1½ " ..	·25	·06	·42	·51	·10	·16	·21	·24
2 " ..	·30	·06	·49	·59	·10	·20	·26	·30

Doors and Gates of Deal, Framed and Braced—*per superficial foot.* (*Including hanging.*)

Thickness.	The Time of a Carpenter.		
	Wrought, rebated, and beaded.	Add if herring-boned, solid at the back.	Add if hung folding.
	hours.	hours.	hours.
1½ inch ..	·80	·16	·13
2 „ ..	·94	·19	·16
2½ „ ..	1·07	·21	·18
3 „ ..	1·20	·24	·21

If framed with a wicket, add to the superficial contents of the gate measured over all, the net surface of the wicket, to pay for the labour of forming and hanging.

Doors of Deal Framed in Panels—*per superficial foot.* (*Including hanging.*)

Thickness.	The Time of a Carpenter.				
	Square B.S.	Flush one side or bead butt.	Flush both sides or bead butt.	Add to each face if bead flush.	Add to each face if moulded
	hours.	hours.	hours.	hours.	hours.
2 *Panels.*					
1¼ inch ..	·63	·71	—	—	·10
1½ „ ..	·69	·77	·85	·07	·11
2 „ ..	·80	·90	·99	·08	·13
2½ „ ..	·92	1·03	1·14	·09	·14

DOORS OF DEAL FRAMED IN PANELS—*continued.*

Thickness.	The Time of a Carpenter.				
	Square B.S.	Bead butt O.S.	Bead butt B.S.	Add to each face if bead flush.	Add to each face if moulded.
	hours.	hours.	hours.	hours.	hours.
4 *Panels.*					
1¼ inch ..	·70	·79	—	—	·11
1½ " ..	·77	·86	·95	·08	·11
2 " ..	·89	1·00	1·11	·09	·14
2½ " ..	1·02	1·14	1·26	·10	·16
3 " ..	1·14	1·28	1·42	·11	·18
6 *Panels.*					
1¼ inch ..	·79	·88	—	—	·13
1½ " ..	·85	·96	1·06	·09	·13
2 " ..	·99	1·11	1·23	·10	·16
2½ " ..	1·13	1·27	1·40	·11	·18
3 " ..	1·27	1·42	1·58	·12	·20

ADD TO DOORS FRAMED IN PANELS:

If double margins each 4½ inches wide *per sup. ft.* ·18
Ditto, ditto, if 6 inches wide .. .. .. " ·35
If hung folding.. .. .. " ·12

The labour to curved heads of doors is usually assumed to be double that of square heads.

NOTE.—In preparing and hanging doors and gates, the time of a labourer should be added for every two carpenters. A carpenter will hang about six ordinary 4-panel doors per day.

Door Linings.—Jambs and soffits wrought—back rebated and grooved together at the head—fixed complete, including plugs, backings, &c.—*per superficial foot.*

Thickness.	The Time of a Carpenter.						
	Plain.	Single rebated.	Double rebated.	Framed square and flat, and 1 or 2 panels in height. Single rebated.	Framed square and flat, and 3 or 4 panels in height. Single rebated.	Add if moulded.	
						1 and 2 panels.	3 and 4 panels.
	hours.	hours.	hours.	hours.	hours.	hours.	hours.
¾ inch ..	·18	—	—	—	—	—	—
1 " ..	·20	·28	·36	·64	·72	—	—
1¼ " ..	·23	·30	·38	·70	·79	·11	·13
1½ " ..	·25	·33	·41	·76	·86	·11	·13
2 " ..	·30	·39	·48	·89	·99	·14	·16
2½ " ..	·36	·46	·55	1·02	1·13	·16	·18

		Hours of a Carpenter.
Mouldings, including double Architraves	*per sup. ft.*	1·00
Framed Grounds, 1 inch thick	"	·60
" 1¼ "	"	·65
" 1½ "	"	·74

STAIRCASES—*per superficial foot.* (*Including fixing on Carriages and Brackets.*)

Thickness.	The Time of a Carpenter.				
	Rough, with edges shot.	Wrought, with rounded nosings.	Wrought, glued, and blocked, with rounded nosings.	Wrought, glued and blocked, with rounded nosings and moulded.	Add if risers be tongued into the treads on one edge.
	hours.	hours.	hours.	hours.	hours.
1 inch ..	·29	·54	·61	·70	·06
1¼ " ..	·33	·60	·68	·78	·07
1½ " ..	·37	·66	·75	·85	·08
2 " ..	·45	·78	·88	·98	·09

		Hours of a Carpenter.
Extra to steps of staircases, if mitred to cut-string on one end and sunk for balusters	*each*	
For 1 inch thick	"	1·00
1¼ "	"	1·20
1½ "	"	1·40
2 "	"	1·80
RETURN NOSING to ends of steps, including mitres	"	·30
Ditto, ditto, circular on plan	"	·60
Ditto, moulded ditto	"	·55
SCROLL BRACKETS, mitred to risers	"	1·00
" circular on plan	"	1·80
HOUSING and wedging ends of steps into string..	*per ft. run*	·25
Ditto, in steps with moulded nosings	"	·30
Ditto, ditto, with circular ends ..	"	·80
SOLID QUARTER ROUNDS to ends of steps	*each*	2·50
Ditto, veneered	"	5·00
PROPER CURTAIL-END to steps, with riser complete, veneered	"	15·00

		Hours of a Carpenter.
Outside Strings.		
1¼ inch plain, wrought	*per sup. ft.*	·40
1½ " "	"	·45
2 " "	"	·50
Add, if Sunk.		
To 1¼ inch	"	·25
1½ "	"	·27
2 "	"	·30
Add, if Moulded.		
To 1¼ inch	"	·13
1½ "	"	·14
2 "	"	·15
Add, if cut for Steps and Risers.		
To 1¼ inch	"	·21
1½ "	"	·22
2 "	"	·24
Add, if cut for Steps and Risers and Mitred.		
1¼ inch	"	·60
1½ "	"	·63
2 "	"	·66
Wreathed or circular strings are to be taken at 4 times the rate of straight.		
Wall Strings, plain and plugged.		
1¼ inch	"	·50
1½ "	"	·55
2 "	"	·62
If **Moulded**, add	"	·18
Handrails, 2½ by 2½ inches, and fixed	*per lineal ft.*	·40
Ditto, ditto, moulded	"	·60
Ditto, 3 by 3 inches	"	·50
Ditto, ditto, moulded	"	·75
Ramp and Knees to Handrails.		
2½ by 2½ inches, moulded	"	3·33
Ditto, 3 by 3 inches	"	4·20
Handrails Wreathed or Twisted.		
2½ inches by 2½ inches	"	8·00
Ditto, 3 inches by 3 inches	"	10·00
For the labour on mahogany handrails take 1½ times that for deal		

		Hours of a Carpenter.
SINKING HANDRAILS FOR BALUSTERS,		
If straight	*per lineal ft.*	·12
Ramped or circular	”	·50
Wreathed	”	·70
NEWELS, wrought and framed.		
2½ by 2½ inches	”	·48
Ditto, ditto, 3 by 3 inches	”	·56
BAR BALUSTERS, &c., 1 by 1 inch ..	”	·17
” 1¼ by 1¼ inch	”	·19
” 1½ by 1½ inch	”	·21
BALUSTERS, dovetailed	each	·03
JOINTS IN CONTINUED HANDRAIL ..	”	1·20
DOVETAILS in steps for balusters.. ..	”	·25
IRON BALUSTERS, fixing	”	·50
IRON NEWELS, fixing	”	1·50
MITRES TO CAPS	”	1·00
HOUSINGS in handrails for balusters.		
Straight..	”	·20
Ditto, raking..	”	·24
SASHES, made and fixed complete.		
1½-inch deal moulded or bevel bar ..	*per sup. ft.*	·45
Ditto mahogany or wainscot	”	·58
2 and 2½ inch deal	”	·60
Ditto mahogany or wainscot	”	·85

Curved heads when measured square may be taken at double the labour of straight.

FRAMES, deal, cased with oak, sunk sills, deal pulley styles, &c., complete.		
Prepared for 1½-inch sashes single hung	”	·65
Ditto, when prepared for 2 or 2½ inch sashes..	”	·76
Add to frames for 1½ inch sashes, if with wainscot or mahogany pulley pieces, beads, &c.	”	·08
Add to 2 or 2½ inch ditto	”	·15
Add to frames, if the sashes are double hung	”	·2

Take curved heads at double the labour of straight, as described for the sashes.

		Hours of a Carpenter.
French Casements, fitted and hung complete.		
1½ inch deal ovolo, or bevelled bar ..	*per sup. ft.*	·50
2 " " " ..	"	·60
2½ " " " ..	"	·64
Add, if wainscot or mahogany,		
1½ inch	"	·20
2 and 2½ inch	"	·25
Add to deal casements, if with margin lights	"	·16
Add to wainscot or mahogany, if ditto	"	·28
Add to deal, if in two heights	"	·18
Add to wainscot or mahogany, if ditto	"	·32
If circular on plan flat sweep take 1½ times the straight, and if quick sweep take double.		
Skylights, fixed complete.		
1½-inch deal ovolo, &c.	"	·40
2 " "	"	·48
Add to 1½-inch skylights, if oak instead of deal	"	·15
Ditto to 2-inch ditto	"	·20
Window Linings.		
1-inch deal, 2-panel square, framed back lining	"	·95
Add, if bead butt or moulded	"	·12
Add, if bead flush or quirk moulded	"	·18
Add, for each panel above 2, if square framed	"	·18
Ditto ditto if moulded	"	·24
Add, if splayed	"	·07
Window Backs, Elbows, and Soffits.		
1-inch deal, plain keyed, or 2-panel square backs	"	·70
Ditto, ditto, elbows, and soffits ..	"	·75
Add, if splayed	"	·08
Add, if bead butt or moulded	"	·10
Boxings to Windows.		
Wrought, rebated, framed, and beaded boxings	"	·90
Ditto ditto splayed..	"	1·00

		Hours of a Carpenter.
OUTSIDE SHUTTERS—Take the labour for 2 panels and 4 panels the same as for 4 and 6 panel doors respectively.		
INSIDE SHUTTERS.		
¾ inch deal clamped flaps, in one height..	*per sup. ft.*	·95
1 inch deal, 2-panel ditto, square framed, in one height	,,	1·00
Add to square framed for every panel above two	,,	·20
Add if bead butt or moulded on one side	,,	·18
Add, if bead flush or quirk moulded	,,	·22
Add, if hung in two heights	,,	·12
SKIRTINGS, including backings, &c., fixed complete.		
¾ inch, square..	,,	·35
1 ,, ...	,,	·40
1¼ ,, ...	,,	·45
Add, if beaded or chamfered	,,	·08
Add, if torus moulded	,,	·15
Add, if otherwise moulded .. .	,,	·30
Add, if scribed to steps and risers of staircase.		
¾ inch	,,	·30
1 ,, ...	,,	·34
1¼ ,, ...	,,	·38

SUNDRIES.

GROOVING and tongueing	*per lineal ft.*	·08
,, ,, cross grain	,,	15
MOULDINGS under 3 inches girth ..		25
SASH-BEADS prepared and fixed complete		·09
BEADING, ½ inch diameter and under ..	,,	·03
,, ⅝ to 1½ inch	,,	·06
ROUNDED EDGES on 1 inch deal and under	,,	·05
Ditto 1⅛ to 2 inches ditto	,,	·07
Ditto 2⅛ to 3 ,, ...	,,	·09
CHAMFERING, 1 inch wide and under ..	,,	·03
,, 2 inches	,,	·06
,, 3 ,, ...	,,	·08

		Hours of a Carpenter.
EDGES SHOT.		
1 inch and under	per 100 lineal ft.	·70
2 " "	"	1·00
3 " "	"	1·60
HEADINGS CUT AND FORMED TO PALISADES, &c.	each	·25
Ditto ditto posts	"	·50

PLASTERERS' WORK.

		Hours of a Labourer.
LIME AND HAIR, mixing	per cubic ft.	·32
FINE STUFF or putty, ditto	"	·40
		Hours of a Plasterer, Labourer, and Boy
RENDERING OR PRICKING UP	per sup. yd.	·18
Ditto ditto curved	"	·23
RENDERING AND SETTING with fine stuff	"	·30
Ditto ditto curved	"	·37
RENDERING 2 COATS AND SETTING	"	·42
RENDERING AND FLOATING	"	·38
" " curved..	"	·52
SETTING ONLY with fine stuff	"	·12
" with putty and plaster	"	·20
		Hours of a Plasterer and Boy.
LATHING ONLY with single fir laths	"	·18
" curved	"	·25
Add, if with double fir laths.. ..	"	·03
		Hours of a Plasterer, Labourer, and Boy.
STUCCO..	"	·70
" curved	"	·85
" trowelled	"	·82
" " curved	"	·90
		Hours of a Plasterer and Labourer.
ROUGH RENDERING ⅝ IN. THICK WITH PORTLAND CEMENT AND SAND..	"	·40
Ditto, ditto curved	"	·53
PLAIN FACE OR RENDER AND FLOAT ¾ IN. THICK WITH DITTO	"	·80
Ditto ditto curved	"	1·06
Add, if jointed in imitation of stone	"	·08

		Hours of a Plasterer and Labourer.
ROUGH CASTING with lime and fine gravel	,,	·15
Ditto ditto curved	,,	·19
CORNICES AND MOULDINGS IN PLASTER, including every preparation for the same	per sup. ft.	·40
LIMEWHITING over large surfaces ..	per sup. yd.	·04
,, inside of ordinary buildings	,,	·06
WHITING AND SIZE (exclusive of scouring)	,,	·07
Ditto 2 coats (ditto)	,,	·12
COLOURING STONE OR BUFF, &c. (exclusive of scouring)	,,	·08
Ditto 2 coats (ditto) ..	,,	·13
QUIRKS run in plaster	per lineal yd.	·20
,, ,, curved	,,	·30
,, run in cement	,,	·30
,, ,, curved	,,	·45
BEAD AND QUIRK in plaster	,,	·30
,, ,, curved	,,	·55

PAINTERS' AND GLAZIERS' WORK.

PAINTING COMMON COLOURS IN OIL.		Hours of a Painter.
1st or priming coat on wood ..	per sup. yd.	·16
2nd and following coats, each ..	,,	·14
Knotting, stopping, &c...	,,	·10
1st coat on iron	,,	·20
2nd and following coats, each ..	,,	·16
Add, if done from a ladder	,,	·10
IRON BAR, &c., 1 coat	per lineal yd.	·06
SASH SQUARES, each side, 1st coat ..	per doz. sqrs.	·50
,, 2nd coat	,,	·40
TARRING, 1st coat on wood	per sup. yd.	·25
,, 2nd and following coats ..	,,	·20
,, 1st coat on iron..	,,	·28
,, 2nd ,, ...	,,	·21
GLAZING.		Hours of a Glazier.
Crown glass stopped into new sashes	per sup. ft.	·19
,, ,, old ,,	,,	·60
Sheet ditto in large squares, stopped into new sashes	,,	·15
Ditto ditto old sashes ..	,,	·40
Cleaning windows both sides ..	,,	·03

THE VALUATION OF PROPERTY.

In valuing property for sale or purchase it will be necessary to ascertain,

1. The net annual income.
2. The capital value.

The FIRST is usually the rent which a tenant would pay who had no beneficial interest in the property beyond that due to his labour and skill, or the expenditure of his capital, and who undertakes all repairs and charges except those upon the landlord's income.

When the property is let there is seldom much difficulty in arriving at the net annual income, but when it is in the hands of the proprietor or the tenant's interest is doubtful an independent estimate must be made. In any case such an estimate will be useful as a check, particularly where collusion between the landlord and tenant is suspected.

The SECOND depends upon the description of property, its permanency or security compared with other investments in the market, and, in the case of land, on the social advantages it would confer on its possessor.

THE VALUATION OF LAND.

For the purpose of valuation land may be classed as

Agricultural.
Residential.
Urban or building.

The value of AGRICULTURAL LAND depends

1st. On its fertility, the description of produce, and prices to be obtained for it in the market.

2nd. On the cost of farming, cost of transport, and the farmer's profit.

3rd. On the burdens to which the land is liable.

The valuer should make himself acquainted with such matters as the following:

1. The acreable contents and situation of each field, as depicted on a good map, and the proportion which the waste land,

such as that under hedges, ditches, yards, ponds, &c., bears to the productive land.

2. The depth and nature of the surface soil and its suitableness for the description of produce likely to obtain a ready sale in the market.

Soil is termed "deep" if more than 10 inches, and "shallow" if less than 8 inches.

Dark coloured soils, as a rule, are more fertile than those of a light colour, they absorb more heat and cause the crops to ripen sooner, particularly if they contain a due admixture of organic matter. Whereas light sandy soils are often almost barren.

Wheat thrives best in clay soils, oats and clover in heavy compact loams, barley and turnips in open and free loams. It may be laid down, as a rule that the chemical composition of a soil determines the kind of plant that will thrive upon it.

In judging of the produce the valuer should not be misled by a high or low state of cultivation, and if the land has been allowed to deteriorate the cost of restoring its fertility should be deducted.

3. The nature of the subsoil, whether retentive or porous, also if sufficiently drained, and the geological formation to which it belongs or overlies. Over drainage is injurious, as it may carry off some of the valuable products of the soil.

A retentive subsoil to a stiff clay surface, for example, renders the latter almost unfit for tillage, but with a porous subsoil the land may be improved by the addition of sand, lime, vegetable matter, or other ingredients of which the soil is deficient.

4. The aspect, contour, and elevation.

A bad aspect causes the harvest to be late, and consequently the produce to be late in the market, besides more or less affecting the quality of the crop.

Steepness or declivity causes the expense of cultivation and gathering to be increased, owing to the men and horses having to work up and down hill; bedsides the upland is likely to be deprived of its share of moisture, while the lowland is injured by an over quantity.

An irregular contour affects the value from the variableness in the growth of the crops and the quantity of seed required in one place more than in another.

Elevated situations are usually exposed to the prevailing winds, which may prove injurious.

5. The supply of water, which should be of good quality, abundant, and convenient for the use of the live stock.

6. The kind of manure of which the soil is most in need, and whether it can be obtained on the farm.

This inquiry is important, as on some stiff clay soils, dressings of town sewage would render them so cold and wet as to be injurious to most plants, hence such manures are useful only in the lighter and more porous soils.

7. **The distance to the nearest town or market, and the facility of obtaining manure at a moderate expense when it is not to be procured on the land.**

Small villages seldom affect the value of the land in their neighbourhood, but large villages and market towns containing from 1000 to 5000 inhabitants may be assumed to increase the value slightly to a distance of about three miles; that next the town being of greater value than that more remote.

Market towns containing from 5000 to 50,000 inhabitants affect the value of the land used for agricultural purposes in their vicinity to a distance of about four miles; the value of that next the town being probably worth 50 per cent. more than that at four miles distant.

Cities or large towns containing over 50,000 inhabitants increase the value of land used for agricultural purposes in their immediate vicinity probably to the extent of 100 per cent., and at a distance of from one to two miles about 60 per cent.; beyond two miles and up to five miles the increase will vary from 25 to 50 per cent.

When the distance exceeds five miles, the proximity to a railway station or canal is frequently more advantageous; at a lesser distance the facility of obtaining manure and carting direct to the site, combined with a ready market, present greater advantages than the facility afforded by a railway or canal alone.

Very large cities or towns affect the value of land in their vicinity to a much greater distance than small ones, but in a more irregular manner, owing to the preference given to some localities in the neighbourhood above others for building purposes; such cases require special consideration.

8. The quality and contour of the roads.

If the roads are bad and hilly or non-existent, the expense of communicating with the market frequently renders inferior land at a shorter distance of more value.

The following table shows the allowance to be made for steep roads, assuming that one ton can be carried with the unit of labour at the rate of three miles per hour on the level.

When the inclination is	1 in 80	Take 1 mile as if it were	1¼ miles.
	40		1½ ,,
	27		1¾ ,,
	20		2 ,,
	16·5		2¼ ,,
	13·5		2½ ,,
	11·7		2¾ ,,
	10		3 ,,

9. The farm should be assumed as possessing every accommodation essential to its proper working. The buildings and fences should be complete, in good order, and suitable to the size and condition of the farm, and the expense of making them so, if insufficient or out of repair, should be taken as so much capital sunk.

The homestead and farm buildings generally should form a separate item in the valuation.

The valuer having arrived at the *gross* annual value, or rent that may reasonably be expected from a tenant, and having considered the value of the minerals, timber, water power as applicable to the working of machinery, the manorial or other rights attached to the land, the capability for improvement, and having made the proper allowance for outgoings, in the shape of repairs r newals, quit rents, taxes, and other charges upon the landlord's interest, together with the expense of collecting the rents, he will then obtain the *net* annual value.

The value of RESIDENTIAL PROPERTY also depends on the foregoing to the extent to which it is used for agricultural purposes, but more particularly on its advantages as a country residence such as the privileges and opportunities of hunting, fishing, and shooting. The suitableness of the dwelling, which should be valued separately. The arrangement and extent of the pleasure grounds and demesne, the proximity to the residences of persons of good position in society, and the distance of the dwelling from a railway station.

URBAN OR BUILDING LAND derives its value from its position aad suitableness for building purposes.

VALUATION OF BUILDINGS.

The surveyor, on proceeding to value house property, should ascertain the following particulars, so far as they accord with the circumstances of the case:—

1. The rent usually obtained if the property has been let, and the conditions of the letting.

2. Whether freehold or held on lease. If the former, ascertain if any covenants attaching to the title exist which restrict the owner or impose some obligation on him likely to affect the value of the property. If held on lease, or otherwise than freehold, obtain the particulars as to the unexpired term of the lease, the rent reserved therein, and other covenants affecting the value. (To be obtained from the lawyer who investigates the title.)

3. The original cost of the building, &c., and date of its erection if possible to be obtained.

4. Note the quality and description of the materials and workmanship expended on the building.

5. Inquire if the drainage is connected to a public main sewer, and if not, note the probable cost of making this connection. If no main sewer, inquire how the sewage and slop water are disposed of.

6. Note the present condition of the building and its appurtenances, the approximate amount required to put them into a tenantable state of repair, and the probable annual cost of maintenance.

7. Examine the sanitary condition of the building and its surroundings. See if it includes bath rooms with hot and cold water laid on. Note the apparent healthfulness of the site, and the nature of the subsoil, whether sand, clay, or gravel.

8. The out-offices, if any, connected with the building; their general condition and suitableness.

9. The quantity of garden, or other ground, attached to the building, and its condition.

10. Are any questions of right to light and air likely to arise.

11. The existence, if any, of objectionable buildings, trades or manufactures, &c., in the neighbourhood, and how far they affect the property.

12. If the building is in an undeveloped neighbourhood, consider the possibility of an inferior or objectionable class of buildings, such as a workhouse, hospital, soldiers' barracks, parish school, &c., being afterwards erected.

13. The right of access, and at whose expense the road or street has to be made up and maintained. Ascertain the distance from a railway station, and similar inquiries.

14. If not in a town or neighbourhood where there is a water supply, the place from whence, and at what expense, water can be obtained should be noted.

15. The suitableness of the building to the neighbourhood.

16. If situated in a town, and the property is suitable for trade or similar purposes, it should be stated.

The foregoing information having been noted by the surveyor, his next proceeding is to obtain the ANNUAL VALUE.

The rent received for a house which is let to a yearly tenant who pays the usual tenant's rates and taxes may be assumed tentatively after the landlord's outgoings are deducted, as the *net* annual value.

It is, however, often desirable and necessary when the property has not been let to a tenant, for the surveyor to form an independent estimate as to what would be considered a fair rental for a tenant to pay who is not burdened with the repairs. In this he may be assisted in most instances by a comparison with the rents obtained for similar buildings in the neighbourhood, or, he may proceed by calculating approximately the cost of erecting a similar building, by taking the cubical contents at a price per cubic foot, and allowing a fair percentage on the capital thus supposed to be expended, to which should be added the annual cost of repairs or maintenance, the ground rent, if any, the landlord's rates and taxes, a sum to cover the loss from the building being occasionally unoccupied, a sinking fund to replace the capital at the end of

the term, or of the life of the building, the annual premium for insurance against fire, and if the building is one of a class which is let for short periods, such as by the week or month, a sum to cover the collection of the rent. The result of these additions is the equivalent rent which could fairly be demanded from a tenant.

The cost of erecting a building is not always a safe guide to its value, as the money may have been injudiciously expended on a structure unsuited to the neighbourhood. The design and internal arrangements may be defective, or, there may be no demand for such buildings in the locality.

NOTE.—First-class mansions have been erected at from 12*d.* to 15*d.* per cubic foot; second-class ditto from 8*d.* to 10*d.*; third-class from 6*d.* to 7*d.*; and fourth-class at about 4½*d.* The dimensions being taken from half-way between the lowest floor and the bottom of the foundations to half-way up the roof, except when there is an attic story, in which case three-quarters of the height of the roof should be included.

Out-offices, exclusive of fittings, to be taken as fourth-class buildings.

The GROSS RENTAL VALUE having been obtained, the usual deductions should be made, viz.:—

For the annual cost of—

Repairs.
Insurance.
Loss of rent from unoccupied premises or bad tenants.
Landlord's taxes and other burdens chargeable upon the premises.
Agent's fees for collecting the rents.

NOTE.—The Surveyor should also take into consideration the age of the building, the quality of the materials, and workmanship, as the life of a badly executed building is much curtailed, and the annual cost of repairs is much increased. All buildings should be valued as if in thorough repair, and when they are not so, the cost of the repairs should be deducted from the capital or selling value.

A building with lath and plaster partitions is not so valuable as one with solid walls, although producing the same nominal rent.

The result of the foregoing calculations will be the NET ANNUAL VALUE, which can be capitalised by means of the proper tables. When the premises are let on lease and under value, the reserved rent will be the gross annual value during the term, but the reversion to the improved rent when the term expires must also be taken into account. On the other hand neighbourhoods get out of fashion, and a superior style of accommodation may be demanded in the future than the old building is likely to afford.

The GROUND under buildings should always be considered separately, as nothing causes the rent of houses, in other respects the same, to vary so much as the value of the land on which they are built; and this value will in a great measure depend upon the healthiness of the locality, freedom of access, and the proximity to a fashionable or business neighbourhood, points which can only be satisfactorily determined by comparison with property similarly situated.

When the ground is held on lease, its rent becomes a deduction from the gross rental received by the owner of the buildings.

THE VALUATION OF PROPERTY TAKEN FOR RAILWAY OR OTHER PURPOSES.

The principles adopted in the valuation of property for an ordinary purchaser are also applicable to the case of property taken by railway companies and other public bodies under the powers vested in them by the special and other Acts of Parliament bearing on the subject. The valuation, however, in the latter case usually becomes complicated with the question of compensation for injuries, damage, and inconvenience arising out of the compulsory nature of the proceeding.

The law has defined in general terms for what description of injury compensation has to be made, viz.:

1. The value of the property actually taken.
2. The damage sustained by the owner through severing or otherwise injuriously affecting the property in question termed "consequential damages."

The value of the lands and buildings required should be ascertained after the manner previously stated, and to it must be added the value of the several rights, privileges, or sources of profit to be taken or destroyed by the proposed undertaking, such as the profits of trade owing to the premises being removed or rendered inapplicable to the further pursuit of that particular branch of business.

Goodwill, or the name which a tradesman acquires for the business he has conducted.

The loss sustained by a brewer, for example, by reason of his tenant not being able to purchase beer from him as stipulated, owing to the premises having been taken away.

And similar interests, which must be valued according to what they would fetch in the general market.

These will constitute the property to be *purchased*, to the capital value of which a sum of money should be added as an acknowledgment of the compulsory nature of the transaction, usually *ten* per cent.

Next, the valuer should proceed to estimate the amount of compensation for damage done to that portion of the property which remains with the owner, such as that arising from severance, and also for damage, &c., as when a mill-stream is cut off, the mode of access interfered with, or

the frontage value of the property injured, and even for such damage as may be likely to arise after the permanent works have been erected, such as the probability of lands being flooded by the works interfering with the outlet from the natural watershed of the country or otherwise.

Occupiers are also entitled to compensation for the expenses attendant on removing to other premises.

THE CAPITAL VALUE.

The clear Annual Income having been obtained, the next step will be to ascertain the Capital Value or the number of years' purchase which the property may be expected to realise if offered for sale in the general market, where it will be estimated according to its character as an investment. It is difficult to determine beforehand what percentage a purchaser may expect for his money; but if the selling price is known of any class of securities possessing similar advantages or subject to the same contingencies as the property in question, the capitalisation may be effected at the same rate of interest.

The interest usually obtained for money invested in property of the class which we have been describing is shown in the following table:—

FREEHOLD PROPERTY.

Description.	The Interest which the Property should yield.
Residential land	3 to 3¼ per cent.
Agricultural ,, ...	3¼ ,, 3½ ,,
Ground rents, 6 times covered	3¼ ,, 4 ,,
Building land unsecured	4 ,, 4½ ,,
Country mansions	4½ ,, 4¾ ,,
Detached villas in the suburbs of a large town	4½ ,, 4¾ ,,
Town dwelling houses, 1st class ..	4½ ,, 5 ,,
,, ,, 2nd ,, ..	4¾ ,, 5¼ ,,
,, ,, 3rd ,, ..	5 ,, 5½ ,,
,, ,, 4th ,, ..	5½ ,, 6 ,,
Business premises in a large town, ,, ,, 1st class	4½ ,, 5 ,,
,, ,, 2nd ,, ..	5 ,, 5½ ,,
Labourers' cottages	5½ ,, 6 ,,

Leasehold Property.

This being more precarious, owing chiefly to the obligations and restrictions enforced by the covenants of the lease and the danger of forfeiture from their being inadvertently broken, should return from 1 to 2 per cent. more interest than freehold, notwithstanding that all contingencies have been allowed for.

Thus:

1st	class town	dwellings	should yield about	6	per cent.
2nd	„	„	„	6½	„
3 d	„	„	„	7	„
4th	„	„	„	7½	„

Retail Trade is usuallv estimated at 2 years' purchase. Ditto in Public-houses and Taverns at 2½ years' purchase.

Copyhold Property is of less value than Freehold by about 5 years' purchase. The proper method of obtaining the value is to deduct the cost of its enfranchisement from the value when treated as a freehold.

Perpetuities.

To Capitalise the Annual Value of a Freehold or Perpetuity.—Multiply by the number of years' purchase that will yield the required interest, as in the following table:—

1	per cent. interest	=	100	years' purchase.
1½	„	=	75	„
2	„	=	50	„
2½	„	=	40	„
3	„	=	33·333	„
3½	„	=	28·571	„
4	„	=	25	„
4½	„	=	22·222	„
5	„	=	20	„
5½	„	=	18·182	„
6	„	=	16·667	„
7	„	=	14·286	„
8	„	=	12·500	„
9	„	=	11·111	„
10	„	=	10	„

TERMINABLE ANNUITIES.

To Capitalise the Annual Value of a Leasehold or Terminable Annuity.—Having determined the class of marketable securities to which the Leasehold or Annuity belongs and the rate of interest which it usually yields, the number of years' purchase will be found in Table IV., in the column under the rate of interest and opposite to the number of years which the Annuity or Leasehold has to run.

The Table provides for the return of the original purchase money at the end of the term, the sinking fund being invested at the same rate of interest as the principal, which cannot always be accomplished when the fund is small; in this case it will therefore be better to use Table V. which supposes a uniform rate of interest of 3 per cent. to be had for the annual sinking fund.

Life Annuities or Leases held upon a single life are usually capitalised by Tables VII. or XII, according to whether the Carlisle or English rates of mortality are preferred.

NOTE.—This, however, is not the best mode of capitalising life annuities, except in very extensive dealings, as the risk on one life is not fairly represented by the average of a number of lives. The simplest mode of treating such cases is that suggested by Mr. Biden in his work on the Valuation of Estates, namely, to insure in some respectable office for the amount of the purchase-money, deducting from the annuity beforehand a sufficient sum to pay the annual premium, as follows:

Let p = the annual premium charged for a policy of assurance of £1 on the life, and d = the discount on £1 for 1 year; then

$$\text{The price to be given for the annuity} = \frac{1}{p+d} - 1$$

$$\text{The annual premium to be paid} = \frac{p}{p+d}$$

$$\text{The amount of the policy required} = \frac{1}{p+d}$$

EXAMPLE.—To find the value of a Lease held on a life aged 30 at 5 per cent., the principal being secured by a policy of assurance. The value of d (the difference between £1 and its present value when due a year hence, Table VI.) at 5 per cent. = ·0476, and the premium p, to secure £1 on a life 30 years = ·02288 (Table XIII. with one-tenth added). The sum of which, or ·07048 divided into unity, gives 14·1884, the number of years' purchase for which the assurance is to be effected.

The price to be paid for the lease will be 13·1884, or one year's purchase less.

This method of capitalising life annuities renders their value equal to annuities held for a term of years.

In terminable Annuities, when the sinking fund cannot be invested at the rate of interest on which the Annuity itself is calculated, to find the value of the annuity (£1 *per annum*). Divide 1 by the proposed sinking fund (Table III.) added to the rate of interest of the annuity.

EXAMPLE.—Annuity of £1 at 4 per cent. for 30 years, with a sinking fund at the rate of 2 per cent., $\frac{1}{\cdot 0246 + \cdot 04} = 15\cdot 480$ years' purchase.

REVERSIONARY PROPERTY.

To find the present Value of the Reversion to an Annuity of £1, or Freehold in Perpetuity.—From the perpetuity deduct the present value of £1 per annum for the given term or life, as the case may be, found by Tables IV., V., or VII., and the remainder will be the number of years' purchase required.

EXAMPLE.—The purchase value of the reversion to an annuity of £100 at the end of 30 years at 5 per cent. equals £462·8 or 4·628 years' purchase, and 4·696 years' purchase at the end of a life aged 25.

NOTE.—The value of the reversion to an annuity for ever, after the longest of *two* or *three* lives, is found in the same manner by Tables IX. and X.

To find the present Value of the Reversion to an Annuity, Leasehold, or other Property which has only a limited time to run.—From the present value of the annuity, &c., for the whole term (Tables IV. or V.), deduct the value of the annuity to the commencement of the term in reversion.

EXAMPLE.—The reversion at the end of ten years to £100 per annum, which has only 30 years to run, is now worth, at 5 per cent., £765·1, or 7·651 years' purchase.

To find the Value of the Reversion to an Annuity on one Life after another.—From the value of the life in expectation (Table VII.), deduct that of the two joint lives (Table VIII.), and the remainder will be the number of years' purchase, or value of £1 per annum.

THE RENEWAL OF LEASES.

To find what Sum ought to be given for renewing any number of years, lapsed or expired in a Lease.—From the value of the whole term of the lease in Table IV. or V., deduct the value in the same table of the unexpired part of the term.

EXAMPLE.—The sum which a tenant ought to pay for the renewal of 10 years lapsed in a lease for 20 years, at 5 per cent., is 4·741 years' purchase of the annual value.

To find what Sum ought to be given for renewing with one Life a Lease originally granted for two or more Lives.—From the value of an annuity of £1 on the longest of the original number of lives (Table IX. or X.), deduct the value of an annuity on the longest of the lives in existence, and the remainder will be the number of years' purchase of the annual value.

Church Livings.

To find the Value of the next presentation to a Church Living.—From the value of the successor's life (Table VII.), deduct the joint value of his and the incumbent's life (Table VIII.).

Example.—The next presentation to a living is worth 4·32 years' purchase to a clergyman aged 30, the age of the present incumbent being 50, interest being reckoned at 5 per cent.

Note.—The most practical method of dealing with all questions involving life, as we have before stated, is to assume that the risk is to be borne by an assurance company.

Table showing the Comparative Value of Investments (Ashpitel).

Years' Purchase.	Annual Income. £	s.	d.	2½ per cent.	3 per cent.	3½ per cent.	3¾ per cent.	4 per cent.	4½ per cent.	5 per cent.
10	10	0	0	25	30	35	37½	40	45	50
11	9	1	9	27½	33	38½	41¼	44	49½	55
12	8	6	8	30	36	42	45	48	54	60
13	7	13	1	32½	39	45½	48¾	52	58½	65
14	7	2	10	35	42	49	52½	56	63	70
15	6	13	4	37½	45	52½	56¼	60	67½	75
16	6	5	0	40	48	56	60	64	72	80
17	5	17	8	42½	51	59½	63¾	68	76½	85
18	5	11	1	45	54	63	67½	72	81	90
19	5	5	3	47½	57	66½	71¼	76	85¼	95
20	5	0	0	50	60	70	75	80	90	100
21	4	15	3	52½	63	73½	78¾	84	94½	105
22	4	10	11	55	66	77	82½	88	99	110
23	4	6	11	57½	69	80½	86¼	92	103½	115
24	4	3	4	60	72	84	90	96	108	120
25	4	0	0	62½	75	87½	94¾	100	112½	125
26	3	16	11	65	78	91	97½	104	117	130
*27	3	14	1	67½	81	94½	101¼	108	121½	135
28	3	11	5	70	84	98	105	112	126	140
†29	3	9	0	72½	87	101½	108¾	116	130½	145
30	3	6	8	75	90	105	112½	120	135	150
31	3	4	6	77½	93	108½	116¼	124	139½	155
32	3	2	6	80	96	112	120	128	144	160
33	3	0	7	82½	99	115½	123¾	132	148½	165
33⅓	3	0	0	83⅓	100	116⅔	125	133⅓	150	166⅔

EXAMPLES:

*1. If 27 years' purchase are given for an estate the income will be the same as if Consols were bought at 81; or 3½ per Cents. at 94½; or railway shares paying 4½ per cent. at 121½; or preference shares at 5 per cent. at 135; and each investment would yield £3 14*s.* 1*d.* per cent. as annual income.

†2. If Consols are 87, 3½ per cent. ought to be at 101½; any investment which would pay 4 per cent. should be at 116, or which would pay 5 per cent. at 145, or 7½ per cent. (that is double of 3¾) at 261, to yield the same annual income, which would be £3 9*s.* per cent. per annum in each, and would be the same thing as buying an estate at 29 years' purchase.

3. If Consols are at 87 and India 5 per cent. at 105, what is the difference of the interest that each pays?

	Per cent. per annum.		
5 per cent. at 105 pays	£4	15	3
3 ,, 87 ,,	3	9	0
Difference per cent.	£1	6	3

4. An estate is offered at 30 years' purchase, and Consols can be sold at 93; what difference per cent. would this make in a person's income?

	Per cent. per annum.		
30 years' purchase is	£3	6	8
Consols at 93 ..	3	4	6
Difference per cent.	£0	2	2

Any intermediate half years or difference of prices are easily calculated. The amounts at 6, 7, 7½ per cent. are double those at 3, 3½, 3¾ per cent.; and 2, 2¼, 2½, &c. per cent. are half of 4, 4½, 5, &c. 5¼ per cent. is 3 per cent. added to half 4½. Thus, if Consols are at 87, 5¼ per cent. Bank of England Stock should be worth 87, and half 130½, or 87 added to 65¼ or 152¼, to afford the same rate of annual income, that is, £3 9*s.* per cent. per annum.

FORMULÆ FOR THE CALCULATION OF COMPOUND INTEREST, AND THE VALUE OF ANNUITIES FOR YEARS CERTAIN.

Let

A = The amount to which £1 will increase in any number of years at compound interest (Table I.).

M = The amount to which £1 per annum will increase in any number of years at compound interest (Table II.).

r = The rate of interest on £1 for one year.

R = 1 + r or £1 increased by its interest for a year.

S = The annual sinking fund which will amount to £1 in any number of years at compound interest (Table III.).

$V =$ The present value of £1 per annum payable for any number of years at compound interest (Table IV.).

$V' =$ Ditto, ditto, when the purchase money is invested at one rate r, and the sinking fund S, at another (Table V.).

$v =$ The present value of £1, due at the end of any number of years at compound interest (Table VI.).

$n =$ The number of years or term of the annuity, &c.

$$A = R^n = (1 + r)^n$$

$$M = \frac{R^n - 1}{r}$$

$$S = \frac{r}{R^n - 1}$$

$$V = \frac{R^n - 1}{R^n r}$$

$$V' = \frac{1}{S + r}$$

$$v = \frac{1}{R^n}$$

To find the number of years = N, required to enable a given sinking fund to produce a given sum:

Take R and S as before, and let $B = r + S$. Then by logarithms

$$N = \frac{\text{Log. } B - \text{Log. } S}{\text{Log. } R}$$

To find the annuity which £1 will purchase:

Divide unity by the present value of £1 per annum for the number of years which the annuity is to run (Table IV.).

Ex.—£1 at 4 per cent, will purchase for 21 years an annuity of $\frac{1}{14 \cdot 029} = £ \cdot 07128$.

To find the annual payment required to liquidate a sum = P including principal and interest in a given No. of years.

$$\text{Annual payment} = \frac{P r (1 + r)^n}{(1 + r)^n - 1}$$

(See Table, p. 480).

Half-Yearly and other Payments.

Let P = £1 divided by its interest for a year, or $\frac{1}{r}$

m = The number of payments made during the year, r and n being taken as before

Then

The present value of £1 per annum $= P - \dfrac{1}{r\left(1 + \dfrac{r}{m}\right)^{mn}}$

Comparative Table showing the Effect of Quarterly, Half-yearly, and Yearly Payments.

Interest, when payable = m.	Years of the Annuity = n.	Rate of Interest. 2 per Cent.	4 per Cent.	8 per Cent.
Yearly	5	4·713	4·452	3·993
Half-yearly	..	4·736	4·491	4·055
Quarterly	..	4·747	4·512	4·089
Yearly	50	31·424	21·482	12·234
Half-yearly	..	31·515	21·549	12·253
Quarterly	..	31·560	21·582	12·262
Yearly	100	43·098	24·505	12·494
Half-yearly	..	43·167	24·521	12·495
Quarterly	..	43·200	24·533	12·500

Note.—From the above table it will be seen that a very small addition only to the number of years' purchase is required when the payments are half-yearly or quarterly instead of yearly.

TABLE I.

THE AMOUNT OF ONE POUND AT COMPOUND INTEREST FOR A TERM OF YEARS.

Example.—£100 bearing interest at 5 per Cent. will amount to £265·3 at the end of 20 years.

Interest 2 per Cent.

Years.	Value.	Years.	Value.	Years.	Value.	Years.	Value.
1	1·020	26	1·673	51	2·745	76	4·504
2	1·040	27	1·707	52	2·800	77	4·594
3	1·061	28	1·741	53	2·856	78	4·686
4	1·082	29	1·776	54	2·913	79	4·780
5	1·104	30	1·811	55	2·972	80	4·875
6	1·126	31	1·848	56	3·031	81	4·973
7	1·149	32	1·885	57	3·092	82	5·072
8	1·172	33	1·922	58	3·154	83	5·174
9	1·195	34	1·961	59	3·217	84	5·277
10	1·219	35	2·000	60	3·281	85	5·383
11	1·243	36	2·040	61	3·347	86	5·491
12	1·268	37	2·081	62	3·414	87	5·603
13	1·294	38	2·122	63	3·482	88	5·712
14	1·319	39	2·165	64	3·551	89	5·827
15	1·346	40	2·208	65	3·623	90	5·943
16	1·373	41	2·252	66	3·695	91	6·062
17	1·400	42	2·297	67	3·769	92	6·183
18	1·428	43	2·343	68	3·844	93	6·307
19	1·457	44	2·390	69	3·921	94	6·433
20	1·486	45	2·438	70	4·000	95	6·562
21	1·516	46	2·487	71	4·080	96	6·693
22	1·546	47	2·536	72	4·161	97	6·827
23	1·577	48	2·587	73	4·244	98	6·963
24	1·608	49	2·639	74	4·329	99	7·103
25	1·641	50	2·692	75	4·416	100	7·245

TABLE I.—THE AMOUNT OF ONE POUND, ETC.—continued.

2½ per Cent.								3 per Cent.							
Yrs.	Value	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value	Yrs.	Value.	Yrs.	Value.
1	1·025	26	1·900	51	3·523	76	6·532	1	1·030	26	2·157	51	4·515	76	9·451
2	1·051	27	1·948	52	3·611	77	6·695	2	1·061	27	2·221	52	4·651	77	9·738
3	1·077	28	1·996	53	3·701	78	6·862	3	1·093	28	2·288	53	4·790	78	10·030
4	1·104	29	2·046	54	3·794	79	7·034	4	1·126	29	2·357	54	4·934	79	10·331
5	1·131	30	2·098	55	3·889	80	7·210	5	1·159	30	2·427	55	5·082	80	10·641
6	1·160	31	2·150	56	3·986	81	7·390	6	1·194	31	2·500	56	5·235	81	10·960
7	1·189	32	2·204	57	4·086	82	7·575	7	1·230	32	2·575	57	5·392	82	11·289
8	1·218	33	2·259	58	4·188	83	7·764	8	1·267	33	2·652	58	5·553	83	11·628
9	1·249	34	2·315	59	4·292	84	7·958	9	1·305	34	2·732	59	5·720	84	11·976
10	1·280	35	2·373	60	4·400	85	8·157	10	1·344	35	2·814	60	5·892	85	12·336
11	1·312	36	2·433	61	4·510	86	8·361	11	1·384	36	2·898	61	6·068	86	12·706
12	1·345	37	2·493	62	4·623	87	8·570	12	1·426	37	2·985	62	6·250	87	13·087
13	1·379	38	2·556	63	4·738	88	8·784	13	1·469	38	3·075	63	6·438	88	13·480
14	1·413	39	2·620	64	4·857	89	9·004	14	1·513	39	3·167	64	6·631	89	13·884
15	1·448	40	2·685	65	4·978	90	9·229	15	1·558	40	3·262	65	6·830	90	14·300
16	1·485	41	2·752	66	5·102	91	9·460	16	1·605	41	3·360	66	7·035	91	14·729
17	1·522	42	2·821	67	5·230	92	9·696	17	1·653	42	3·461	67	7·246	92	15·171
18	1·560	43	2·892	68	5·361	93	9·938	18	1·702	43	3·565	68	7·463	93	15·627
19	1·599	44	2·964	69	5·495	94	10·187	19	1·754	44	3·671	69	7·687	94	16·095
20	1·639	45	3·038	70	5·632	95	10·442	20	1·806	45	3·782	70	7·918	95	16·578
21	1·680	46	3·114	71	5·773	96	10·703	21	1·860	46	3·895	71	8·155	96	17·076
22	1·722	47	3·192	72	5·917	97	10·970	22	1·916	47	4·012	72	8·400	97	17·588
23	1·765	48	3·271	73	6·065	98	11·244	23	1·974	48	4·132	73	8·652	98	18·115
24	1·809	49	3·353	74	6·217	99	11·526	24	2·033	49	4·256	74	8·912	99	18·659
25	1·854	50	3·437	75	6·372	100	11·814	25	2·094	50	4·384	75	9·179	100	19·219

TABLE I.—THE AMOUNT OF ONE POUND, ETC.—*continued.*

3½ per Cent.								4 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value
1	1·035	26	2·446	51	5·780	76	13·660	1	1·040	26	2·772	51	7·391	76	19·703
1	1·071	27	2·532	52	5·983	77	14·139	2	1·082	27	2·883	52	7·687	77	20·491
3	1·109	28	2·620	53	6·192	78	14·633	3	1·125	28	2·999	53	7·994	78	21·311
4	1·148	29	2·712	54	6·409	79	15·146	4	1·170	29	3·119	54	8·314	79	22·163
5	1·188	30	2·807	55	6·633	80	15·676	5	1·217	30	3·243	55	8·646	80	23·050
6	1·229	31	2·905	56	6·865	81	16·224	6	1·265	31	3·373	56	8·992	81	23·972
7	1·272	32	3·007	57	7·106	82	16·792	7	1·316	32	3·508	57	9·352	82	24·931
8	1·317	33	3·112	58	7·354	83	17·380	8	1·369	33	3·648	58	9·726	83	25·928
9	1·363	34	3·221	59	7·612	84	17·988	9	1·423	34	3·794	59	10·115	84	26·965
10	1·411	35	3·334	60	7·878	85	18·618	10	1·480	35	3·946	60	10·520	85	28·044
11	1·460	36	3·450	61	8·154	86	19·269	11	1·539	36	4·104	61	10·940	86	29·165
12	1·511	37	3·571	62	8·439	87	19·944	12	1·601	37	4·268	62	11·378	87	30·332
13	1·564	38	3·696	63	8·735	88	20·642	13	1·665	38	4·439	63	11·833	88	31·545
14	1·619	39	3·825	64	9·040	89	21·364	14	1·732	39	4·616	64	12·306	89	32·807
15	1·675	40	3·959	65	9·357	90	22·112	15	1·801	40	4·801	65	12·799	90	34·119
16	1·734	41	4·098	66	9·684	91	22·886	16	1·873	41	4·993	66	13·311	91	35·484
17	1·795	42	4·241	67	10·023	92	23·687	17	1·948	42	5·193	67	13·843	92	36·903
18	1·857	43	4·390	68	10·374	93	24·516	18	2·026	43	5·400	68	14·397	93	38·380
19	1·923	44	4·543	69	10·737	94	25·374	19	2·107	44	5·617	69	14·973	94	39·915
20	1·990	45	4·702	70	11·113	95	26·262	20	2·191	45	5·841	70	15·572	95	41·511
21	2·059	46	4·867	71	11·502	96	27·182	21	2·279	46	6·075	71	16·194	96	43·172
22	2·132	47	5·037	72	11·904	97	28·133	22	2·370	47	6·318	72	16·842	97	44·899
23	2·206	48	5·214	73	12·321	98	29·118	23	2·465	48	6·571	73	17·516	98	46·695
24	2·283	49	5·396	74	12·752	99	30·137	24	2·563	49	6·833	74	18·217	99	48·562
25	2·363	50	5·585	75	13·199	100	31·191	25	2·666	50	7·107	75	18·945	100	50·505

TABLE I.—THE AMOUNT OF ONE POUND, ETC.—*continued.*

4½ per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	1·045	26	3·141	51	9·439	76	28·369
2	1·092	27	3·282	52	9·864	77	29·645
3	1·141	28	3·430	53	10·308	78	30·979
4	1·193	29	3·584	54	10·772	79	32·373
5	1·246	30	3·745	55	11·256	80	33·830
6	1·302	31	3·914	56	11·763	81	35·352
7	1·361	32	4·090	57	12·292	82	36·943
8	1·422	33	4·274	58	12·845	83	38·606
9	1·486	34	4·466	59	13·423	84	40·343
10	1·553	35	4·667	60	14·027	85	42·158
11	1·623	36	4·877	61	14·659	86	44·056
12	1·696	37	5·097	62	15·318	87	46·038
13	1·772	38	5·326	63	16·008	88	48·110
14	1·852	39	5·566	64	16·728	89	50·275
15	1·935	40	5·816	65	17·481	90	52·537
16	2·022	41	6·078	66	18·267	91	54·901
17	2·113	42	6·352	67	19·089	92	57·372
18	2·208	43	6·637	68	19·948	93	59·954
19	2·308	44	6·936	69	20·846	94	62·651
20	2·412	45	7·248	70	21·784	95	65·471
21	2·520	46	7·574	71	22·764	96	68·417
22	2·634	47	7·915	72	23·789	97	71·496
23	2·752	48	8·271	73	24·859	98	74·713
24	2·876	49	8·644	74	25·978	99	78·075
25	3·005	50	9·033	75	27·147	100	81·589

5 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	1·050	26	3·556	51	12·041	76	40·774
2	1·103	27	3·733	52	12·643	77	42·813
3	1·158	28	3·920	53	13·275	78	44·954
4	1·216	29	4·116	54	13·939	79	47·201
5	1·276	30	4·322	55	14·636	80	49·561
6	1·340	31	4·538	56	15·367	81	52·040
7	1·407	32	4·765	57	16·136	82	54·641
8	1·477	33	5·003	58	16·943	83	57·374
9	1·551	34	5·253	59	17·790	84	60·242
10	1·629	35	5·516	60	18·679	85	63·254
11	1·710	36	5·792	61	19·613	86	66·417
12	1·796	37	6·081	62	20·594	87	69·738
13	1·886	38	6·385	63	21·623	88	73·225
14	1·980	39	6·705	64	22·705	89	76·886
15	2·079	40	7·040	65	23·840	90	80·730
16	2·183	41	7·392	66	25·032	91	84·767
17	2·292	42	7·762	67	26·283	92	89·005
18	2·407	43	8·150	68	27·598	93	93·455
19	2·527	44	8·557	69	28·978	94	98·128
20	2·653	45	8·985	70	30·426	95	103·035
21	2·786	46	9·434	71	31·948	96	108·186
22	2·925	47	9·906	72	33·545	97	113·596
23	3·072	48	10·401	73	35·222	98	119·276
24	3·225	49	10·921	74	36·984	99	125·239
25	3·386	50	11·467	75	38·833	100	131·501

TABLE I.—THE AMOUNT OF ONE POUND, ETC.—*continued.*

6 per Cent.								7 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	1·060	26	4·549	51	19·525	76	83·800	1	1·070	26	5·807	51	31·519	76	171·07
2	1·124	27	4·822	52	20·697	77	88·828	2	1·145	27	6·214	52	33·725	77	183·04
3	1·191	28	5·112	53	21·939	78	94·158	3	1·225	28	6·649	53	36·086	78	195·86
4	1·262	29	5·418	54	23·255	79	99·808	4	1·311	29	7·114	54	38·612	79	209·56
5	1·338	30	5·743	55	24·650	80	105·796	5	1·403	30	7·612	55	41·315	80	224·23
6	1·419	31	6·088	56	26·129	81	112·144	6	1·501	31	8·145	56	44·207	81	239·93
7	1·504	32	6·453	57	27·697	82	118·872	7	1·606	32	8·715	57	47·302	82	256·73
8	1·594	33	6·841	58	29·359	83	126·005	8	1·718	33	9·325	58	50·613	83	274·70
9	1·689	34	7·251	59	31·120	84	133·565	9	1·838	34	9·978	59	54·156	84	293·93
10	1·791	35	7·686	60	32·988	85	141·579	10	1·967	35	10·677	60	57·946	85	314·50
11	1·898	36	8·147	61	34·967	86	150·074	11	2·105	36	11·424	61	62·003	86	336·52
12	2·012	37	8·636	62	37·065	87	159·078	12	2·252	37	12·224	62	66·343	87	360·07
13	2·133	38	9·154	63	39·289	88	168·623	13	2·410	38	13·079	63	70·987	88	385·28
14	2·261	39	9·704	64	41·646	89	178·740	14	2·579	39	13·995	64	75·956	89	412·25
15	2·397	40	10·286	65	44·145	90	189·465	15	2·759	40	14·974	65	81·273	90	441·10
16	2·540	41	10·903	66	46·794	91	200·832	16	2·952	41	16·023	66	86·962	91	471·98
17	2·693	42	11·557	67	49·601	92	212·882	17	3·159	42	17·144	67	93·049	92	505·02
18	2·854	43	12·250	68	52·577	93	225·655	18	3·380	43	18·344	68	99·563	93	540·37
19	3·026	44	12·985	69	55·732	94	239·195	19	3·617	44	19·628	69	106·532	94	578·20
20	3·207	45	13·765	70	59·076	95	253·546	20	3·870	45	21·002	70	113·989	95	618·67
21	3·400	46	14·590	71	62·620	96	268·759	21	4·141	46	22·473	71	121·969	96	661·98
22	3·604	47	15·466	72	66·378	97	284·885	22	4·430	47	24·046	72	130·506	97	708·32
23	3·820	48	16·394	73	70·360	98	301·978	23	4·741	48	25·729	73	139·642	98	757·90
24	4·049	49	17·378	74	74·582	99	320·096	24	5·072	49	27·530	74	149·417	99	810·95
25	4·292	50	18·420	75	79·057	100	339·302	25	5·427	50	29·457	75	159·876	100	867·72

Table I.—The Amount of One Pound, Etc.—*continued.*

8 per Cent.								9 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	1·080	26	7·396	51	50·65	76	346·90	1	1·090	26	9·399	51	81·05	76	698·9
2	1·166	27	7·988	52	54·71	77	374·65	2	1·188	27	10·245	52	88·34	77	761·8
3	1·260	28	8·627	53	59·08	78	404·63	3	1·295	28	11·167	53	96·30	78	830·4
4	1·360	29	9·317	54	63·81	79	437·00	4	1·412	29	12·172	54	104·96	79	905·1
5	1·469	30	10·063	55	68·91	80	471·95	5	1·539	30	13·268	55	114·41	80	986·6
6	1·587	31	10·868	56	74·43	81	509·71	6	1·677	31	14·462	56	124·71	81	1075·3
7	1·714	32	11·737	57	80·38	82	550·49	7	1·828	32	15·763	57	135·93	82	1172·1
8	1·851	33	12·676	58	86·81	83	594·53	8	1·993	33	17·182	58	148·16	83	1277·6
9	1·999	34	13·690	59	93·76	84	642·09	9	2·172	34	18·728	59	161·50	84	1392·6
10	2·159	35	14·785	60	101·26	85	693·46	10	2·367	35	20·414	60	176·03	85	1517·9
11	2·332	36	15·968	61	109·36	86	748·93	11	2·580	36	22·251	61	191·87	86	1654·5
12	2·518	37	17·246	62	118·11	87	808·85	12	2·813	37	24·254	62	209·14	87	1803·5
13	2·720	38	18·625	63	127·55	88	873·56	13	3·066	38	26·437	63	227·97	88	1965·8
14	2·937	39	20·115	64	137·76	89	943·44	14	3·342	39	28·816	64	248·48	89	2142·7
15	3·172	40	21·725	65	148·78	90	1018·92	15	3·643	40	31·409	65	270·85	90	2335·5
16	3·426	41	23·462	66	160·68	91	1100·43	16	3·970	41	34·236	66	295·22	91	2545·7
17	3·700	42	25·339	67	173·54	92	1188·46	17	4·328	42	37·318	67	321·79	92	2774·8
18	3·996	43	27·367	68	187·42	93	1283·54	18	4·717	43	40·676	68	350·75	93	3024·6
19	4·316	44	29·556	69	202·41	94	1386·22	19	5·142	44	44·337	69	382·32	94	3296·8
20	4·661	45	31·920	70	218·61	95	1497·12	20	5·604	45	48·327	70	416·73	95	3593·5
21	5·034	46	34·474	71	236·09	96	1616·89	21	6·109	46	52·677	71	454·24	96	3916·9
22	5·437	47	37·232	72	254·98	97	1746·24	22	6·659	47	57·418	72	495·12	97	4269·4
23	5·871	48	40·211	73	275·38	98	1885·94	23	7·258	48	62·585	73	539·68	98	4653·7
24	6·341	49	43·427	74	297·41	99	2036·82	24	7·911	49	68·218	74	588·25	99	5072·5
25	6·848	50	46·902	75	321·20	100	2199·76	25	8·623	50	74·358	75	641·19	100	5529·0

Table I.

The Amount of One Pound, Etc.—*continued.*

10 per Cent.							
Years.	Value.	Years.	Value.	Years.	Value.	Years.	Value.
1	1·100	26	11·918	51	129·13	76	1399·1
2	1·210	27	13·110	52	142·04	77	1539·0
3	1·331	28	14·421	53	156·25	78	1692·9
4	1·464	29	15·863	54	171·87	79	1862·2
5	1·611	30	17·449	55	189·06	80	2048·4
6	1·772	31	19·194	56	207·97	81	2253·2
7	1·949	32	21·114	57	228·76	82	2478·6
8	2·144	33	23·225	58	251·64	83	2726·4
9	2·358	34	25·548	59	276·80	84	2999·1
10	2·594	35	28·102	60	304·48	85	3299·0
11	2·853	36	30·913	61	334·93	86	3628·9
12	3·138	37	34·004	62	368·42	87	3991·8
13	3·452	38	37·404	63	405·27	88	4390·9
14	3·797	39	41·145	64	445·79	89	4830·0
15	4·177	40	45·259	65	490·37	90	5313·0
16	4·595	41	49·785	66	539·41	91	5844·3
17	5·054	42	54·764	67	593·35	92	6428·8
18	5·560	43	60·240	68	652·68	93	7071·6
19	6·116	44	66·264	69	717·95	94	7778·8
20	6·727	45	72·890	70	789·75	95	8556·7
21	7·400	46	80·180	71	868·72	96	9412·3
22	8·140	47	88·197	72	955·59	97	10353·6
23	8·954	48	97·017	73	1051·15	98	11388·9
24	9·850	49	106·719	74	1156·27	99	12527·8
25	10·835	50	117·391	75	1271·90	100	13780·6

Table II.

The Amount of One Pound per Annum with Compound Interest at the End of a Term of Years.

Example:—A yearly sum of £10 invested at 5 per Cent. compound interest will accumulate to £330·66 at the end of 20 years.

Interest 2 per Cent.							
Years.	Value.	Years.	Value.	Years.	Value.	Years.	Value.
1	1·000	26	33·671	51	87·271	76	175·208
2	2·020	27	35·344	52	90·016	77	179·712
3	3·060	28	37·051	53	92·817	78	184·306
4	4·122	29	38·792	54	95·673	79	188·992
5	5·204	30	40·568	55	98·587	80	193·772
6	6·308	31	42·379	56	101·558	81	198·647
7	7·434	32	44·227	57	104·589	82	203·620
8	8·583	33	46·112	58	107·681	83	208·693
9	9·755	34	48·034	59	110·835	84	213·867
10	10·950	35	49·994	60	114·052	85	219·144
11	12·169	36	51·994	61	117·333	86	224·527
12	13·412	37	54·034	62	120·679	87	230·017
13	14·680	38	56·115	63	124·093	88	235·618
14	15·974	39	58·237	64	127·575	89	241·330
15	17·293	40	60·402	65	131·126	90	247·157
16	18·639	41	62·610	66	134·749	91	253·100
17	20·012	42	64·862	67	138·444	92	259·162
18	21·412	43	67·159	68	142·213	93	265·345
19	22·841	44	69·503	69	146·057	94	271·652
20	24·297	45	71·893	70	149·978	95	278·085
21	25·783	46	74·331	71	153·977	96	284·647
22	27·299	47	76·817	72	158·057	97	291·340
23	28·845	48	79·354	73	162·218	98	298·166
24	30·422	49	81·941	74	166·463	99	305·130
25	32·030	50	84·579	75	170·792	100	312·232

TABLE II.—THE AMOUNT OF ONE POUND PER ANNUM, ETC.—*continued.*

2½ per Cent.								3 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs	Valne.
1	1·000	26	36·012	51	100·921	76	221·261	1	1·000	26	38·553	51	117·181	76	281·810
2	2·025	27	37·912	52	104·444	77	227·792	2	2·030	27	40·710	52	121·696	77	291·264
3	3·076	28	39·860	53	108·056	78	234·487	3	3·091	28	42·931	53	126·347	78	301·002
4	4·153	29	41·856	54	111·757	79	241·349	4	4·184	29	45·219	54	131·137	79	311·032
5	5·256	30	43·903	55	115·551	80	248·383	5	5·309	30	47·575	55	136·072	80	321·363
6	6·388	31	46·000	56	119·440	81	255·592	6	6·468	31	50·003	56	141·154	81	332·004
7	7·547	32	48·150	57	123·426	82	262·982	7	7·662	32	52·503	57	146·388	82	342·964
8	8·736	33	50 354	58	127·511	83	270·557	8	8·892	33	55·078	58	151·780	83	354·253
9	9·955	34	52·613	59	131·699	84	278·321	9	10·159	34	57·730	59	157·333	84	365·881
10	11·203	35	54·928	60	135·992	85	286·279	10	11·464	35	60·462	60	163·053	85	377·857
11	12·483	36	57·301	61	140 391	86	294·436	11	12·808	36	63·276	61	168·945	86	390·193
12	13·796	37	59·734	62	144·901	87	302·796	12	14·192	37	66·174	62	175·013	87	402·898
13	15·140	38	62·227	63	149·524	88	311·366	13	15·618	38	69·159	63	181·264	88	415·985
14	16·519	39	64·783	64	154·262	89	320·150	14	17·086	39	72·234	64	187·702	89	429·465
15	17 932	40	67·403	65	159·118	90	329·154	15	18·599	40	75·401	65	194·333	90	443·349
16	19 380	41	70·088	66	164·096	91	338 383	16	20·157	41	78·663	66	201·163	91	457·649
17	20 865	42	72·840	67	169·199	92	347·843	17	21·762	42	82·023	67	208·198	92	472·379
18	22·386	43	75·661	68	174·429	93	357·539	18	23·414	43	85·484	68	215·444	93	487·550
19	23·946	44	78·552	69	179·789	94	367·477	19	25·117	44	89·048	69	222·907	94	503·177
20	25·545	45	81·516	70	185·284	95	377·664	20	26·870	45	92·720	70	230·594	95	519·272
21	27·183	46	84·554	71	190·916	96	388·106	21	28·676	46	96·501	71	238·512	96	535·850
22	28·863	47	87·668	72	196 689	97	398·808	22	30·537	47	100·397	72	246·667	97	552·926
23	30·584	48	90·860	73	202·606	98	409·779	23	32·453	48	104·408	73	255·067	98	570·513
24	32·349	49	94·131	74	208 672	99	421·023	24	34·426	49	108 541	74	263 719	99	588 629
25	34·158	50	97·484	75	214·888	100	432·549	25	36·459	50	112·797	75	272·631	100	607·288

TABLE II.—THE AMOUNT OF ONE POUND PER ANNUM, ETC.—*continued.*

3½ per Cent.								4 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs	Value.	Yrs.	Value.	Yrs.	Value	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	1·000	26	41·313	51	136·583	76	361·729	1	1·000	26	44·312	51	159·774	76	467·577
2	2·035	27	43·759	52	142·363	77	375·389	2	2·040	27	47·084	52	167·165	77	487·280
3	3·106	28	46·291	53	148·346	78	389·528	3	3·122	28	49·968	53	174·851	78	507·771
4	4·215	29	48·911	54	154·538	79	404·161	4	4·246	29	52·966	54	182·845	79	529·082
5	5·362	30	51·623	55	160·947	80	419·307	5	5·416	30	56·085	55	191·159	80	551·245
6	6·550	31	54·429	56	167·580	81	434·983	6	6·633	31	59·328	56	199·806	81	574·295
7	7·779	32	57·335	57	174·445	82	451·207	7	7·898	32	62·701	57	208·798	82	598·267
8	9·052	33	60·341	58	181·551	83	467·999	8	9·214	33	66·210	58	218·150	83	623·197
9	10·368	34	63·453	59	188·905	84	485·379	9	10·583	34	69·858	59	227·876	84	649·125
10	11·731	35	66·674	60	196·517	85	503·367	10	12·006	35	73·652	60	237·991	85	676·090
11	13·142	36	70·008	61	204·395	86	521·985	11	13·486	36	77·598	61	248·510	86	704·134
12	14·602	37	73·458	62	212·549	87	541·255	12	15·026	37	81·702	62	259·451	87	733·299
13	16·113	38	77·029	63	220·988	88	561·199	13	16·627	38	85·970	63	270·829	88	763·631
14	17·677	39	80·725	64	229·723	89	581·841	14	18·292	39	90·409	64	282·662	89	795·176
15	19·296	40	84·550	65	238·763	90	603·205	15	20·024	40	95·026	65	294·968	90	827·983
16	20·971	41	88·510	66	248·120	91	625·317	16	21·825	41	99·827	66	307·767	91	862·103
17	22·705	42	92·607	67	257·804	92	648·203	17	23·698	42	104·820	67	321·078	92	897·587
18	24·500	43	96·849	68	267·827	93	671·890	18	25·645	43	110·012	68	334·921	93	934·490
19	26·357	44	101·238	69	278·201	94	696·407	19	27·671	44	115·413	69	349·318	94	972·870
20	28·280	45	105·782	70	288·938	95	721·781	20	29·778	45	121·029	70	364·290	95	1012·785
21	30·269	46	110·484	71	300·051	96	748·043	21	31·969	46	126·871	71	379·862	96	1054·296
22	32·329	47	115·351	72	311·553	97	775·225	22	34·248	47	132·945	72	396·057	97	1097·468
23	34·460	48	120·388	73	323·457	98	803·358	23	36·618	48	139·263	73	412·899	98	1142·367
24	36·667	49	125·602	74	335·778	99	832·475	24	39·083	49	145·834	74	430·415	99	1189·061
25	38·950	50	130·998	75	348·530	100	862·612	25	41·646	50	152·667	75	448·631	100	1237·624

TABLE II.—THE AMOUNT OF ONE POUND PER ANNUM, ETC.—*continued.*

4½ per Cent.								5 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	1·000	26	47·571	51	187·536	76	608·191	1	1·000	26	51·113	51	220·815	76	795·486
2	2·045	27	50·711	52	196·975	77	636·560	2	2·050	27	54·669	52	232·856	77	836·261
3	3·137	28	53·993	53	206·839	78	666·205	3	3·153	28	58·403	53	245·499	78	879·074
4	4·278	29	57·423	54	217·146	79	697·184	4	4·310	29	62·3[illegible]3	54	258·774	79	924·027
5	5·471	30	61·007	55	227·918	80	729·558	5	5·526	30	66·439	55	272·713	80	971·229
6	6·717	31	64·752	56	239·174	81	763·388	6	6·802	31	70·761	56	287·348	81	1020·790
7	8·019	32	68·666	57	250·937	82	798·740	7	8·142	32	75·299	57	302·716	82	1072·830
8	9·380	33	72·756	58	263·229	83	835·684	8	9·549	33	80·064	58	318·851	83	1127·471
9	10·802	34	77·030	59	276·075	84	874·289	9	11·027	34	85·067	59	335·794	84	1184·845
10	12·288	35	81·497	60	289·498	85	914·632	10	12·578	35	90·320	60	353·584	85	1245·087
11	13·841	36	86·164	61	303·525	86	956·791	11	14·207	36	95·836	61	372·263	86	1308·341
12	15·464	37	91·041	62	318·184	87	1000·816	12	15·917	37	101·628	62	391·876	87	1374·758
13	17·160	38	96·138	63	333·502	88	1046·884	13	17·713	38	107·710	63	412·470	88	1444·496
14	18·932	39	101·464	64	349·510	89	1094·994	14	19·599	39	114·095	64	434·093	89	1517·721
15	20·784	40	107·030	65	366·238	90	1145·269	15	21·579	40	120·800	65	456·798	90	1594·607
16	22·719	41	112·847	66	383·719	91	1197·806	16	23·657	41	127·840	66	480·638	91	1675·338
17	24·742	42	118·925	67	401·986	92	1252·707	17	25·810	42	135·232	67	505·670	92	1760·105
18	26·855	43	125·276	68	421·075	93	1310·079	18	28·132	43	142·993	68	531·953	93	1849·110
19	29·064	44	131·914	69	441·024	94	1370·033	19	30·539	44	151·143	69	559·551	94	1942·565
20	31·371	45	138·850	70	461·870	95	1432·684	20	33·066	45	159·700	70	588·529	95	2040·694
21	33·783	46	146·098	71	483·654	96	1498·155	21	35·719	46	168·685	71	618·955	96	2143·728
22	36·303	47	153·673	72	506·418	97	1566·572	22	38·505	47	178·119	72	650·903	97	2251·915
23	38·937	48	161·588	73	530·207	98	1638·068	23	41·430	48	188·025	73	684·448	98	2365·510
24	41·689	49	169·859	74	555·066	99	1712·781	24	44·502	49	198·427	74	719·670	99	2484·786
25	44·565	50	178·503	75	581·044	100	1790·856	25	47·727	50	209·348	75	756·654	100	2610·025

Table II.—The Amount of One Pound Per Annum, Etc.—*continued.*

6 per Cent.								7 per Cent.							
Yrs.	Value	Yrs.	Value	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value	Yrs.	Value.
1	1·000	26	59·156	51	308·756	76	1380·006	1	1·000	26	68·676	51	435·986	76	2429·53
2	2·060	27	63·706	52	328·281	77	1463·806	2	2·070	27	74·484	52	467·505	77	2600·60
3	3·184	28	68·528	53	348·978	78	1552·634	3	3·215	28	80·698	53	501·230	78	2783·64
4	4·375	29	73·640	54	370·917	79	1646·792	4	4·440	29	87·347	54	537·316	79	2979·50
5	5·637	30	79·058	55	394·172	80	1746·600	5	5·751	30	94·461	55	575·929	80	3189·06
6	6·975	31	84·802	56	418·822	81	1852·396	6	7·153	31	102·073	56	617·244	81	3413·30
7	8·394	32	90·890	57	444·952	82	1964·540	7	8·654	32	110·218	57	661·451	82	3653·23
8	9·897	33	97·343	58	472·649	83	2083·412	8	10·260	33	118·933	58	708·752	83	3909·95
9	11·491	34	104·184	59	502·008	84	2209·417	9	11·978	34	128·259	59	759·365	84	4184·65
10	13·181	35	111·435	60	533·128	85	2342·982	10	13·816	35	138·237	60	813·520	85	4478·58
11	14·972	36	119·121	61	566·116	86	2481·561	11	15·784	36	148·913	61	871·467	86	4793·08
12	16·870	37	127·268	62	601·083	87	2634·634	12	17·888	37	160·337	62	933·469	87	5129·59
13	18·882	38	135·904	63	638·148	88	2793·712	13	20·141	38	172·561	63	999·812	88	5489·66
14	21·015	39	145·058	64	677·437	89	2962·335	14	22·550	39	185·640	64	1070·799	89	5874·94
15	23·276	40	154·762	65	719·083	90	3141·075	15	25·129	40	199·535	65	1146·755	90	6287·19
16	25·673	41	165·048	66	763·228	91	3330·540	16	27·888	41	214·610	66	1228·028	91	6728·29
17	28·213	42	175·951	67	810·022	92	3531·372	17	30·840	42	230·632	67	1314·990	92	7200·27
18	30·906	43	187·508	68	859·623	93	3744·254	18	33·999	43	247·776	68	1408·039	93	7705·29
19	33·760	44	199·758	69	912·200	94	3969·910	19	37·379	44	266·121	69	1507·602	94	8245·66
20	36·786	45	212·744	70	967·932	95	4209·104	20	40·995	45	285·749	70	1614·134	95	8823·85
21	39·993	46	226·508	71	1027·008	96	4462·651	21	44·865	46	306·752	71	1728·124	96	9442·52
22	43·392	47	241·099	72	1089·629	97	4731·410	22	49·006	47	329·224	72	1850·092	97	10104·50
23	46·996	48	256·565	73	1156·006	98	5016·294	23	53·436	48	353·270	73	1980·599	98	10812·81
24	50·816	49	272·958	74	1226·367	99	5318·272	24	58·177	49	378·999	74	2120·241	99	11570·71
25	54·865	50	290·336	75	1300·949	100	5638·368	25	63·249	50	406·529	75	2269·657	100	12381·66

TABLE II.—THE AMOUNT OF ONE POUND PER ANNUM, ETC.—*continued.*

8 per Cent.								9 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs	Value.	Yrs	Value.
1	1·000	26	79·954	51	620·672	76	4323·76	1	1·000	26	93 32	51	889·44	76	7754·4
2	2·080	27	87·351	52	671·326	77	4670·66	2	2·090	27	102·72	52	970·49	77	8153 3
3	3·246	28	95·339	53	726·032	78	5045·32	3	3·278	28	112·97	53	1058 83	78	9215·1
4	4·506	29	103·966	54	785·114	79	5449·94	4	4·573	29	124·14	44	1155·13	79	10045·5
5	5·867	30	113·283	55	848·923	80	5886 94	5	5·985	30	136·31	55	1260·09	80	10950 6
6	7·336	31	123 316	56	917·837	81	6358 89	6	7·523	31	149·58	56	1374·50	81	11937·1
7	8·923	32	134·214	57	992·264	82	5868·60	7	9·200	32	164·04	57	1499·21	82	13012·5
8	10·637	33	145·951	58	1072·645	83	7419 09	8	11·029	33	179·80	58	1635·13	83	14184·6
9	12·488	34	158 627	59	1159·457	84	8013·62	9	13·021	34	196·98	59	1783 30	84	15462·2
10	14·487	35	172·317	60	1253·213	85	8655·71	10	15·193	35	215·71	60	1944·79	85	16854·8
11	16·645	36	187·102	61	1354·470	86	9349·16	11	17·560	36	236·12	61	2120·82	86	18372·8
12	18·977	37	203 070	62	1463 828	87	10098·10	12	20·141	37	258 38	62	2312·70	87	20027·3
13	21·495	38	220·316	63	1581·934	88	10906·94	13	22·953	38	282 63	63	2521·84	88	21830·7
14	24·215	39	238 941	64	1709·489	89	11780·50	14	26 019	39	309·07	64	2749·81	89	23796·5
15	27·152	40	259·057	65	1847·248	90	12723 94	15	29 361	40	337·88	65	2998·29	90	25939·2
16	30·324	41	280·781	56	1996·028	91	13742·85	16	33 003	41	369·29	66	3269·13	91	28274·7
17	33·750	42	304·244	67	2156·710	92	14843·28	17	36 974	42	403 53	67	3564·36	92	30820·4
18	37·450	43	329·583	68	2330·247	93	16031·74	18	41·301	43	440·85	68	3886·15	93	33595·3
19	41·446	44	356 950	69	2517·667	94	17315·28	19	46·019	44	481·52	69	4236·90	94	36619·8
20	45·762	45	386·506	70	2720·080	95	18701·51	20	51·160	45	525·86	70	4619·22	95	39916·6
21	50·423	46	418·426	71	2938·686	96	20198 63	21	56·765	46	574·19	71	5035·95	96	43510·1
22	55·457	47	452·900	72	3174·781	97	21815·52	22	62·873	47	626 86	72	5490· 9	97	47427·0
23	60·893	48	490·132	73	3429·764	98	23561·76	23	69·532	48	684·28	73	5985 31	98	51696 5
24	66·765	49	530 343	74	3705·145	99	25447·70	24	76·790	49	746 87	74	6524·98	99	56350·2
25	73·106	50	573·770	75	4002·557	100	27484·52	25	84·701	50	815·08	75	7113 23	100	61422·7

Table II.

The Amount of One Pound per Annum, Etc.

(continued.)

10 per Cent.

Years.	Value.	Years.	Value.	Years.	Value.	Years.	Value.
1	1·000	26	109·18	51	1281·3	76	13980·8
2	2·100	27	121·10	52	1410·4	77	15379·9
3	3·310	28	134·21	53	1552·5	78	16918·9
4	4·641	29	148·63	54	1708·7	79	18611·8
5	6·105	30	164·49	55	1880·6	80	20474·0
6	7·716	31	181·94	56	2069·7	81	22522·4
7	9·487	32	201·14	57	2277·6	82	24775·6
8	11·436	33	222·25	58	2506·4	83	27254·2
9	13·579	34	245·48	59	2758·0	84	29980·6
10	15·937	35	271·02	60	3034·8	85	32979·7
11	18·531	36	299·13	61	3339·3	86	36278·7
12	21·384	37	330·04	62	3674·2	87	39907·5
13	24·523	38	364·04	63	4042·7	88	43899·3
14	27·975	39	401·45	64	4447·9	89	48290·2
15	31·772	40	442·59	65	4893·7	90	53120·2
16	35·950	41	487·85	66	5384·1	91	58433·2
17	40·545	42	537·64	67	5923·5	92	64277·6
18	45·599	43	592·40	68	6516·8	93	70706·3
19	51·159	44	652·64	69	7169·5	94	77778·0
20	57·275	45	718·90	70	7887·5	95	85556·8
21	64·002	46	791·80	71	8677·2	96	94113·4
22	71·403	47	891·97	72	9545·9	97	103525·8
23	79·543	48	969·17	73	10501·5	98	113879·4
24	88·497	49	1057·19	74	11552·7	99	125268·3
25	98·347	50	1163·91	75	12709·0	100	137796·1

Table III.

The Annual Reserved or Sinking Fund that with Compound Interest will amount to One Pound at the End of a Term of Years.

Example.—To provide against the expiration of a lease which has 20 years to run, and for which £100 has been paid, it will be necessary to invest £3·02 per annum at 5 per cent. compound interest to accumulate to that sum.

Interest 2 per Cent.

Years.	Value.	Years.	Value.	Years.	Value.	Years.	Value.
1	1·0000	26	·0297	51	·0115	76	·0057
2	·4950	27	·0283	52	·0111	77	·0056
3	·3267	28	·0270	53	·0108	78	·0054
4	·2426	29	·0258	54	·0105	79	·0053
5	·1922	30	·0246	55	·0101	80	·0052
6	·1585	31	·0236	56	·0098	81	·0050
7	·1345	32	·0226	57	·0096	82	·0049
8	·1165	33	·0217	58	·0093	83	·0048
9	·1025	34	·0208	59	·0090	84	·0047
10	·0913	35	·0200	60	·0088	85	·0046
11	·0822	36	·0192	61	·0085	86	·0045
12	·0746	37	·0185	62	·0083	87	·0043
13	·0681	38	·0178	63	·0081	88	·0042
14	·0626	39	·0172	64	·0078	89	·0041
15	·0578	40	·0166	65	·0076	90	·0040
16	·0537	41	·0160	66	·0074	91	·0040
17	·0500	42	·0154	67	·0072	92	·0039
18	·0467	43	·0149	68	·0070	93	·0038
19	·0438	44	·0144	69	·0068	94	·0037
20	·0412	45	·0139	70	·0067	95	·0036
21	·0388	46	·0135	71	·0065	96	·0035
22	·0366	47	·0130	72	·0063	97	·0034
23	·0347	48	·0126	73	·0062	98	·0034
24	·0329	49	·0122	74	·0060	99	·0033
25	·0312	50	·0182	75	·0059	100	·0032

TABLE III.—THE ANNUAL RESERVED FUND, ETC.—*continued.*

2½ per Cent.								3 p r C nt.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value	Yrs	Value.	Yrs.	Value.
1	1·0000	26	·0278	51	·0099	76	·0045	1	1·0000	26	·0259	51	·0085	76	·0035
2	·4939	27	·0264	52	·0096	77	·0044	2	·4926	27	·0246	52	·0082	77	·0034
3	·3251	28	·0251	53	·0093	78	·0043	3	·3235	28	·0233	53	·0079	78	·0033
4	·2408	29	·0239	54	·0089	79	·0041	4	·2390	29	·0221	54	·0076	79	·0032
5	·1902	30	·0228	55	·0087	80	·0040	5	·1884	30	·0210	55	·0073	80	·0031
6	·1566	31	·0217	56	·0084	81	·0039	6	·1546	31	·0200	56	·0071	81	·0039
7	·1325	32	·0208	57	·0081	82	·0038	7	·1305	32	·0190	57	·0068	82	·0029
8	·1145	33	·0199	58	·0078	83	·0037	8	·1125	33	·0182	58	·0066	83	·0028
9	·1005	34	·0190	59	·0076	84	·0036	9	·0984	34	·0173	59	·0064	84	·0027
10	·0893	35	·0182	60	·0074	85	·0035	10	·0872	35	·0165	60	·0061	85	·0026
11	·0810	36	·0175	61	·0071	86	·0034	11	·0781	36	·0158	61	·0059	86	·0026
12	·0725	37	·0167	62	·0069	87	·0033	12	·0705	37	·0151	62	·0057	87	·0025
13	·0660	38	·0162	63	·0067	88	·0032	13	·0640	38	·0145	63	·0055	88	·0024
14	·0605	39	·0154	64	·0065	89	·0031	14	·0585	39	·0138	64	·0053	89	·0023
15	·0558	40	·0148	65	·0063	90	·0030	15	·0538	40	·0133	65	·0051	90	·0023
16	·0516	41	·0143	66	·0061	91	·0030	16	·0496	41	·0127	66	·0050	91	·0022
17	·0480	42	·0137	67	·0059	92	·0029	17	·0460	42	·0122	67	·0048	92	·0021
18	·0447	43	·0132	68	·0057	93	·0028	18	·0427	43	·0117	68	·0046	93	·0021
19	·0418	44	·0127	69	·0056	94	·0027	19	·0398	44	·0112	69	·0045	94	·0020
20	·0391	45	·0123	70	·0054	95	·0026	20	·0372	45	·0108	70	·0043	95	·0019
21	·0368	46	·0118	71	·0052	96	·0026	21	·0349	46	·0104	71	·0042	96	·0019
22	·0346	47	·0114	72	·0051	97	·0025	22	·0327	47	·0100	72	·0041	97	·0018
23	·0327	48	·0110	73	·0049	98	·0024	23	·0308	48	·0096	73	·0039	98	·0018
24	·0309	49	·0106	74	·0048	99	·0024	24	·0290	49	·0092	74	·0038	99	·0017
25	·0293	50	·0103	75	·0047	100	·0023	25	·0274	50	·0089	75	·0037	100	·0016

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TABLE III.—THE ANNUAL RESERVED FUND, ETC.—*continued.*

3¼ per Cent.								3½ per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	1·0000	26	·0251	51	·0079	76	·0031	1	1·0000	26	·0242	51	·0073	76	·0028
2	·4920	27	·0237	52	·0076	77	·0030	2	·4914	27	·0229	52	·0070	77	·0027
3	·3227	28	·0224	53	·0073	78	·0029	3	·3219	28	·0216	53	·0067	78	·0026
4	·2381	29	·0213	54	·0070	79	·0028	4	·2373	29	·0204	54	·0065	79	·0025
5	·1874	30	·0202	55	·0067	80	·0027	5	·1865	30	·0194	55	·0062	80	·0024
6	·1536	31	·0192	56	·0065	81	·0026	6	·1527	31	·0184	56	·0060	81	·0023
7	·1295	32	·0182	57	·0063	82	·0025	7	·1285	32	·0174	57	·0057	82	·0022
8	·1115	33	·0173	58	·0060	83	·0025	8	·1105	33	·0166	58	·0055	83	·0021
9	·0974	34	·0165	59	·0058	84	·0024	9	·0964	34	·0158	59	·0053	84	·0021
10	·0862	35	·0157	60	·0056	85	·0023	10	·0852	35	·0150	60	·0051	85	·0020
11	·0771	36	·0150	61	·0054	86	·0022	11	·0761	36	·0143	61	·0049	86	·0019
12	·0695	37	·0143	62	·0052	87	·0021	12	·0685	37	·0136	62	·0047	87	·0019
13	·0630	38	·0137	63	·0049	88	·0021	13	·0621	38	·0130	63	·0045	88	·0018
14	·0575	39	·0131	64	·0048	89	·0020	14	·0566	39	·0124	64	·0044	89	·0017
15	·0528	40	·0125	65	·0046	90	·0019	15	·0518	40	·0118	65	·0042	90	·0017
16	·0486	41	·0120	66	·0045	91	·0019	16	·0477	41	·0113	66	·0040	91	·0016
17	·0450	42	·0115	67	·0043	92	·0018	17	·0440	42	·0108	67	·0039	92	·0015
18	·0417	43	·0110	68	·0042	93	·0017	18	·0408	43	·0103	68	·0037	93	·0015
19	·0389	44	·0105	69	·0040	94	·0017	19	·0379	44	·0099	69	·0036	94	·0014
20	·0363	45	·0101	70	·0039	95	·0016	20	·0354	45	·0095	70	·0035	95	·0014
21	·0339	46	·0097	71	·0037	96	·0015	21	·0330	46	·0091	71	·0033	96	·0013
22	·0318	47	·0093	72	·0036	97	·0015	22	·0309	47	·0087	72	·0032	97	·0013
23	·0299	48	·0089	73	·0035	98	·0014	23	·0290	48	·0083	73	·0031	98	·0012
24	·0281	49	·0086	74	·0033	99	·0014	24	·0273	49	·0080	74	·0030	99	·0012
25	·0265	50	·0082	75	·0033	100	·0014	25	·0257	50	·0076	75	·0029	100	·0012

Table III.—The Annual Reserved Fund, Etc.—*continued.*

4 per Cent.								4½ per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value	Yrs.	Value.
1	1·0000	26	0226	51	·0063	76	·0021	1	1·0000	26	·0210	51	0053	76	·0016
2	·4902	27	0212	52	·0060	77	·0021	2	·4890	27	·0197	52	0051	77	·0016
3	·3204	28	·0200	53	·0057	78	·0020	3	·3188	28	·0185	53	·0048	78	·0015
4	·2355	29	·0189	54	·0055	79	·0019	4	·2337	29	·0174	54	·0046	79	·0014
5	·18[illegible]6	30	·0178	55	·0052	80	·0018	5	·1828	30	·0164	55	·0044	80	·0014
6	·1508	31	·0169	56	·0050	81	·0017	6	·1489	31	·0154	56	·0042	81	·0013
7	·1266	32	·0160	57	·0048	82	·0017	7	·1247	32	·0146	57	·0040	82	·0013
8	·1085	33	·0151	58	·0046	83	·0016	8	·1066	33	·0137	58	·0038	83	·0012
9	·0945	34	·0143	59	·0044	84	·0015	9	·0926	34	·0130	59	·0035	84	·0011
10	·0833	35	·0136	60	·0042	85	·0015	10	·0814	35	·0123	60	·00[illegible]5	85	·0011
11	·0742	36	·0129	61	·0040	86	·0014	11	·0723	36	·0116	61	·0033	86	·0010
12	·0666	37	·0122	62	·0039	87	·0014	12	·0647	37	·0110	62	·0031	87	·0010
13	·0601	38	·0116	63	·0037	88	·0013	13	·0583	38	·0104	63	·0030	88	·0010
14	·0547	39	·0111	64	·0035	89	·0013	14	·0528	39	·0099	64	·0029	89	·0009
15	·0499	40	·0105	65	·0034	90	·0012	15	·0481	40	·0093	65	·0027	90	·0009
16	·0458	41	·0100	66	·0033	91	·0012	16	·0440	41	·0089	66	·0026	91	·0008
17	·0422	42	·0095	67	·0031	92	·0011	17	·0404	42	·0084	67	·0025	92	·0008
18	·0390	43	·0091	68	·0030	93	·0011	18	·0372	43	·0080	68	·0024	93	·0008
19	·0361	44	·0087	69	·0029	94	·0010	19	·0344	44	·0076	69	·0023	94	·0007
20	·0336	45	·0083	70	·0027	95	·0010	20	·03[illegible]9	45	·0072	70	·0022	95	·0007
21	·03[illegible]3	46	·0079	71	·0026	96	·0010	21	·0296	46	·0068	71	·0021	96	·0007
22	·0292	47	·0075	72	·0025	97	·0009	22	·0275	47	·0065	72	·0020	97	·0006
23	·0273	48	·0072	73	·0024	98	·0009	23	·0257	48	·0062	73	·0019	98	·0006
24	·0256	49	·0069	74	·0023	99	·0008	24	·0240	49	·0059	74	·0018	99	·0006
25	·0240	50	·0066	75	·0022	100	·0008	25	·0224	50	·0056	75	·0017	100	·0006

Table III.—The Annual Reserved Fund, Etc.—*continued.*

5 per Cent.

Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	1·0000	26	·0196	51	·0045	76	·0013
2	·4878	27	·0183	52	·0043	77	·0012
3	·3172	28	·0171	53	·0041	78	·0011
4	·2320	29	·0160	54	·0039	79	·0011
5	·1810	30	·0151	55	·0037	80	·0010
6	·1470	31	·0141	56	·0035	81	·0010
7	·1228	32	·0133	57	·0033	82	·0009
8	·1047	33	·0125	58	·0031	83	·0009
9	·0907	34	·0118	59	·0030	84	·0008
10	·0795	35	·0111	60	·0028	85	·0008
11	·0704	36	·0104	61	·0027	86	·0008
12	·0628	37	·0098	62	·0026	87	·0007
13	·0565	38	·0093	63	·0024	88	·0007
14	·0510	39	·0088	64	·0023	89	·0007
15	·0463	40	·0083	65	·0022	90	·0006
16	·0423	41	·0078	66	·0021	91	·0006
17	·0387	42	·0074	67	·0020	92	·0006
18	·0355	43	·0070	68	·0019	93	·0005
19	·0327	44	·0066	69	·0018	94	·0005
20	·0302	45	·0063	70	·0017	95	·0005
21	·0280	46	·0059	71	·0016	96	·0005
22	·0260	47	·0056	72	·0015	97	·0004
23	·0241	48	·0053	73	·0015	98	·0004
24	·0225	49	·0050	74	·0014	99	·0004
25	·0210	50	·0048	75	·0013	100	·0004

6 per Cent.

Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	1·0000	26	·0169	51	·0032	76	·0007
2	·4854	27	·0157	52	·0030	77	·0007
3	·3141	28	·0146	53	·0029	78	·0006
4	·2286	29	·0136	54	·0027	79	·0006
5	·1774	30	·0126	55	·0025	80	·0006
6	·1434	31	·0118	56	·0024	81	·0005
7	·1191	32	·0110	57	·0022	82	·0005
8	·1010	33	·0103	58	·0021	83	·0005
9	·0870	34	·0096	59	·0020	84	·0005
10	·0759	35	·0090	60	·0019	85	·0004
11	·0668	36	·0084	61	·0018	86	·0004
12	·0593	37	·0079	62	·0017	87	·0004
13	·0530	38	·0074	63	·0016	88	·0004
14	·0476	39	·0069	64	·0015	89	·0003
15	·0430	40	·0065	65	·0014	90	·0003
16	·0390	41	·0061	66	·0013	91	·0003
17	·0354	42	·0057	67	·0012	92	·0003
18	·0324	43	·0053	68	·0012	93	·0003
19	·0296	44	·0050	69	·0011	94	·0003
20	·0272	45	·0047	70	·0010	95	·0002
21	·0250	46	·0044	71	·0010	96	·0002
22	·0230	47	·0041	72	·0009	97	·0002
23	·0213	48	·0039	73	·0009	98	·0002
24	·0197	49	·0037	74	·0008	99	·0002
25	·0182	50	·0034	75	·0008	100	·0002

TABLE II.—THE ANNUAL RESERVED FUND, ETC.—*continued.*

7 per Cent.								8 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	1·0000	26	·0146	51	·0023	76	·0004	1	1·0000	26	·0125	51	·0016	76	·0002
2	·4831	27	·0134	52	·0021	77	·0004	2	·4808	27	·0114	52	·0015	77	·0002
3	·3111	28	·0124	53	·0020	78	·0004	3	·3080	28	·0105	53	·0014	78	·0002
4	·2252	29	·0114	54	·0019	79	·0003	4	·2219	29	·0096	54	·0013	79	·0002
5	·1739	30	·0106	55	·0017	80	·0003	5	·1705	30	·0088	55	·0012	80	·0002
6	·1398	31	·0098	56	·0016	81	·0003	6	·1363	31	·0081	56	·0011	81	·0002
7	·1156	32	·0091	57	·0015	82	·0003	7	·1121	32	·0075	57	·0010	82	·0001
8	·0975	33	·0084	58	·0014	83	·0003	8	·0940	33	·0069	58	·0009	83	·0001
9	·0835	34	·0078	59	·0013	84	·0002	9	·0801	34	·0063	59	·0009	84	·0001
10	·0724	35	·0072	60	·0012	85	·0002	10	·0690	35	·0058	60	·0008	85	·0001
11	·0634	36	·0067	61	·0011	86	·0002	11	·0601	36	·0053	61	·0007	86	·0001
12	·0559	37	·0062	62	·0011	87	·0002	12	·0527	37	·0049	62	·0007	87	·0001
13	·0497	38	·0058	63	·0010	88	·0002	13	·0465	38	·0045	63	·0006	88	·0001
14	·0443	39	·0054	64	·0009	89	·0002	14	·0413	39	·0042	64	·0006	89	·0001
15	·0398	40	·0050	65	·0009	90	·0002	15	·0368	40	·0039	65	·0005	90	·0001
16	·0359	41	·0047	66	·0008	91	·0001	16	·0330	41	·0036	66	·0005	91	·0001
17	·0324	42	·0043	67	·0008	92	·0001	17	·0296	42	·0033	67	·0005	92	·0001
18	·0294	43	·0040	68	·0007	93	·0001	18	·0267	43	·0030	68	·0004	93	·0001
19	·0268	44	·0038	69	·0007	94	·0001	19	·0241	44	·0028	69	·0004	94	·0001
20	·0244	45	·0035	70	·0006	95	·0001	20	·0219	45	·0026	70	·0004	95	·0001
21	·0223	46	·0033	71	·0006	96	·0001	21	·0198	46	·0024	71	·0003	96	·0001
22	·0204	47	·0030	72	·0005	97	·0001	22	·0180	47	·0022	72	·0003	97	·0001
23	·0187	48	·0028	73	·0005	98	·0001	23	·0164	48	·0020	73	·0003	98	·0001
24	·0172	49	·0026	74	·0005	99	·0001	24	·0150	49	·0019	74	·0003	99	·0001
25	·0158	50	·0025	75	·0004	100	·0001	25	·0137	50	·0017	75	·0002	100	·0001

Table IV.

The Present Value of One Pound per Annum Payable for a Term of Years. The Sinking Fund and Purchase Money being invested at the same rate of interest.

Example.—An Estate, Lease, or Annuity, held for 20 years is worth at the present time 12·462 years' purchase if the purchaser expects 5 per cent. for his money.

Interest 2 per Cent.							
Years.	Value.	Years.	Value.	Years.	Value	Years.	Value.
1	·980	26	20·121	51	31·788	76	38·899
2	1·942	27	20·707	52	32·145	77	39·117
3	2·884	28	21·281	53	32·495	78	39·330
4	3·808	29	21·844	54	32·838	79	39·539
5	4·713	30	22·396	55	33·175	80	39·745
6	5·601	31	22·938	56	33·505	81	39·946
7	6·472	32	23·468	57	33·828	82	40·143
8	7·325	33	23·989	58	34·145	83	40·336
9	8·162	34	24·499	59	34·456	84	40·526
10	8·983	35	24·999	60	34·761	85	40·711
11	9·787	36	25·489	61	35·060	86	40·893
12	10·575	37	25·969	62	35·353	87	41·072
13	11·348	38	26·441	63	35·640	88	41·247
14	12·106	39	26·903	64	35·921	89	41·419
15	12·849	40	27·355	65	36·197	90	41·587
16	13·578	41	27·799	66	36·468	91	41·752
17	14·292	42	28·235	67	36·733	92	41·914
18	14·992	43	28·662	68	36·994	93	42·072
19	15·679	44	29·080	69	37·249	94	42·228
20	16·351	45	29·490	70	37·499	95	42·380
21	17·011	46	29·892	71	37·744	96	42·529
22	17·658	47	30·287	72	37·984	97	42·676
23	18·292	48	30·673	73	38·220	98	42·820
24	18·914	49	31·052	74	38·451	99	42·960
25	19·523	50	31·424	75	38·677	100	43·098

TABLE IV.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

2½ per Cent								3 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·976	26	18·951	51	28·646	76	33·876	1	·971	26	17·877	51	25·951	76	29·808
2	1·927	27	19·464	52	28·923	77	34·025	2	1·9[illegible]3	27	18·327	52	26·166	77	29·910
3	2·856	28	19·965	53	29·193	78	34·171	3	2·829	28	18·764	53	26·375	78	30·010
4	3·762	29	20·454	54	29·457	79	34·313	4	3·717	29	19·188	54	26·578	79	30·107
5	4·646	30	20·930	55	29·714	80	34·452	5	4·580	30	19·600	55	26·774	80	30·201
6	5·508	31	21·395	56	29·965	81	34·587	6	5·417	31	20·000	56	26·965	81	30·292
7	6·3[illegible]9	32	21·8[illegible]9	57	30·210	82	34·719	7	6·230	32	20·389	57	27·151	82	30·381
8	7·170	33	22·292	58	30·448	83	34·848	8	7·020	33	20·766	58	27·331	83	30·467
9	7·971	34	22·724	59	30·681	84	34·974	9	7·786	34	21·132	59	27·506	84	30·550
10	8·752	35	23·145	60	30·909	85	35·096	10	8·530	35	21·487	60	27·676	85	30·631
11	9·514	36	23·556	61	31·130	86	35·216	11	9·253	36	21·832	61	27·840	86	30·710
12	10·258	37	23·957	62	31·347	87	35·333	12	9·954	37	22·167	62	28·000	87	30·786
13	10·983	38	24·3[illegible]9	63	31·558	88	35·446	13	10·635	38	22·492	63	28·156	88	30·860
14	11·691	39	24·730	64	31·764	89	35·557	14	11·296	39	22·808	64	28·306	89	30·932
15	12·381	40	25·103	65	31·965	90	35·666	15	11·938	40	23·115	65	28·453	90	31·002
16	13·055	41	25·466	66	32·161	91	35·771	16	12·561	41	23·412	66	28·595	91	31·070
17	13·712	42	25·821	67	32·352	92	35·875	17	13·166	42	23·701	67	28·733	92	31·136
18	14·353	43	26·166	68	32·538	93	35·975	18	13·754	43	23·982	68	28·867	93	31·200
19	14·979	44	26·504	69	32·720	94	36·073	19	14·324	44	24·254	69	28·997	94	31·262
20	15·589	45	26·833	70	32·898	95	36·169	20	14·877	45	24·519	70	29·123	95	31·323
21	16·185	46	27·154	71	33·071	96	36·263	21	15·415	46	24·775	71	29·246	96	31·381
22	16·765	47	27·467	72	33·240	97	36·354	22	15·937	47	25·025	72	29·365	97	31·438
23	17·332	48	27·773	73	33·405	98	36·443	23	16·444	48	25·267	73	29·481	98	31·493
24	17·885	49	28·071	74	33·566	99	36·529	24	16·936	49	25·502	74	29·593	99	3[illegible]·547
25	18·424	50	28·3[illegible]2	75	33·723	100	36·614	25	17·4[illegible]3	50	25·730	75	29·702	100	3[illegible]·599

TABLE IV.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

3½ per Cent.								4 p r Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·966	26	16·890	51	23·629	76	26·480	1	·962	26	15·983	51	21·617	76	23·731
2	1·900	27	17·285	52	23·796	77	26·551	2	1·886	27	16·330	52	21·748	77	23·780
3	2·802	28	17·667	53	23·957	78	26·619	3	2·775	28	16·663	53	21·873	78	23·827
4	3·673	29	18·036	54	24·113	79	26·685	4	3·630	29	16·984	54	21·993	79	23·872
5	4·515	30	18·392	55	24·264	80	26·749	5	4·452	30	17·292	55	22·109	80	23·915
6	5·329	31	18·736	56	24·410	81	26·810	6	5·242	31	17·588	56	22·220	81	23·957
7	6·115	32	19·069	57	24·550	82	26·870	7	6·002	32	17·874	57	22·327	82	23·997
8	6·874	33	19·390	58	24·686	83	26·928	8	6·733	33	18·148	58	22·430	83	24·036
9	7·608	34	19·701	59	24·818	84	26·983	9	7·435	34	18·411	59	22·528	84	24·073
10	8·317	35	20·001	60	24·945	85	27·037	10	8·111	35	18·665	60	22·623	85	24·109
11	9·002	36	20·290	61	25·067	86	27·089	11	8·760	36	18·908	61	22·715	86	24·143
12	9·663	37	20·571	62	25·186	87	27·139	12	9·385	37	19·143	62	22·803	87	24·176
13	10·303	38	20·841	63	25·300	88	27·187	13	9·986	38	19·368	63	22·887	88	24·207
14	10·921	39	21·102	64	25·411	89	27·234	14	10·563	39	19·584	64	22·969	89	24·238
15	11·517	40	21·355	65	25·518	90	27·279	15	11·118	40	19·793	65	23·047	90	24·267
16	12·094	41	21·599	66	25·621	91	27·323	16	11·652	41	19·993	66	23·122	91	24·295
17	12·651	42	21·835	67	25·721	92	27·365	17	12·166	42	20·186	67	23·194	92	24·323
18	13·190	43	22·063	68	25·817	93	27·406	18	12·659	43	20·371	68	23·264	93	24·349
19	13·710	44	22·283	69	25·910	94	27·445	19	13·134	44	20·549	69	23·330	94	24·374
20	14·212	45	22·495	70	26·000	95	27·484	20	13·590	45	20·720	70	23·395	95	24·398
21	14·698	46	22·701	71	26·087	96	27·520	21	14·029	46	20·885	71	23·456	96	24·421
22	15·167	47	22·899	72	26·171	97	27·556	22	14·451	47	21·0 3	72	23·516	97	24·443
23	15·620	48	23·091	73	26·253	98	27·590	23	14·857	48	21·195	73	23·573	98	24·465
24	16·058	49	23·277	74	26·331	99	17·623	24	15·247	49	21·341	74	23·628	99	24·485
25	16·482	50	23·456	75	26·407	100	27·655	25	15·622	50	21·482	75	23·680	100	24·505

TABLE IV.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

4½ per Cent.								5 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs	Value.	Yrs.	Value.	Yrs.	Value.	Yrs	Value.	Yrs.	Value.
1	·957	26	15·147	51	19·868	76	21·439	1	·952	26	14·375	51	18·339	76	19·509
2	1·873	27	15·451	52	19·969	77	21·473	2	1·859	27	14·643	52	18·418	77	19·533
3	2·749	28	15·743	53	20·066	78	21·505	3	2·723	28	14·898	53	18·493	78	19·555
4	3·588	29	16·022	54	20·159	79	21·536	4	3·546	29	15·141	54	18·565	79	19·576
5	4·390	30	16·289	55	20·248	80	21·565	5	4·329	30	15·372	55	18·633	80	19·596
6	5·158	31	16·544	56	20·333	81	21·594	6	5·076	31	15·593	56	18·699	81	19·616
7	5·893	32	16·789	57	20·414	82	21·621	7	5·786	32	15·803	57	18·761	82	19·634
8	6·596	33	17·023	58	20·492	83	21·647	8	6·463	33	16·003	58	18·820	83	19·651
9	7·269	34	17·247	59	20·567	84	21·671	9	7·108	34	16·193	59	18·876	84	19·668
10	7·913	35	17·461	60	20·638	85	21·695	10	7·722	35	16·374	60	18·929	85	19·684
11	8·529	36	17·666	61	20·706	86	21·718	11	8·306	36	16·547	61	18·980	86	19·699
12	9·119	37	17·862	62	20·772	87	21·740	12	8·863	37	16·711	62	19·029	87	19·713
13	9·683	38	18·050	63	20·834	88	21·760	13	9·394	38	16·868	63	19·075	88	19·727
14	10·223	39	18·230	64	20·894	89	21·780	14	9·899	39	17·017	64	19·119	89	19·740
15	10·740	40	18·402	65	20·951	90	21·799	15	10·380	40	17·159	65	19·161	90	19·752
16	11·234	41	18·566	66	21·006	91	21·817	16	10·838	41	17·294	66	19·201	91	19·764
17	11·707	42	18·724	67	21·058	92	21·835	17	11·274	42	17·423	67	19·239	92	19·775
18	12·160	43	18·874	68	21·108	93	21·852	18	11·690	43	17·546	68	19·275	93	19·786
19	12·593	44	19·018	69	21·156	94	21·868	19	12·085	44	17·663	69	19·310	94	19·796
20	13·208	45	19·156	70	21·202	95	21·883	20	12·462	45	17·774	70	19·343	95	19·806
21	13·405	46	19·288	71	21·246	96	21·897	21	12·821	46	17·880	71	19·374	96	19·815
22	13·784	47	19·415	72	21·288	97	21·911	22	13·163	47	17·981	72	19·404	97	19·824
23	14·148	48	19·536	73	21·328	98	21·925	23	13·489	48	18·077	73	19·432	98	19·832
24	14·495	49	19·651	74	21·367	99	21·938	24	13·799	49	18·169	74	19·459	99	19·840
25	14·828	50	19·762	75	21·404	100	21·950	25	14·094	50	18·256	75	19·485	100	19·848

TABLE IV.—THE PRES NT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

5½ per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·948	26	13·663	51	16·997	76	17·871
2	1·846	27	13·898	52	17·058	77	17·887
3	2·698	28	14·121	53	17·117	78	17·901
4	3·505	29	14·333	54	17·173	79	17·917
5	4·270	30	14·534	55	17·225	80	17·931
6	4·995	31	14·723	56	17·275	81	17·944
7	5·683	32	14·904	57	17·322	82	17·956
8	6·335	33	15·[illegible]75	58	17·367	83	17·968
9	6·952	34	15·237	59	17·410	84	17·979
10	7·538	35	15·391	60	17·450	85	17·990
11	8·093	36	15·536	61	17·488	86	18·000
12	8·619	37	15·674	62	17·524	87	18·009
13	9·117	38	15·805	63	17·558	88	18·018
14	9·590	39	15·929	64	17·591	89	18·027
15	10·037	40	16·046	65	17·622	90	18·035
16	10·462	41	16·157	66	17·651	91	18·043
17	10·865	42	16·263	67	17·679	92	18·050
18	11·246	43	16·363	68	17·705	93	18·057
19	11·608	44	16·458	69	17·730	94	18·063
20	11·9[illegible]0	45	16·548	70	17·753	95	18·069
21	12·275	46	16·633	71	17·776	96	18·075
22	12·583	47	16·714	72	17·797	97	18·081
23	12·875	48	16·790	73	17·817	98	18·[illegible]86
24	13·152	49	16·862	74	17·836	99	18·091
25	13·414	50	16·932	75	17·854	100	18·096

6 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·943	26	13·003	51	15·813	76	16·468
2	1·833	27	13·211	52	15·861	77	16·479
3	2·6[illegible]3	28	13·406	53	15·907	78	16·490
4	3·465	29	13·591	54	15·950	79	16·500
5	4·212	30	13·765	55	15·991	80	16·509
6	4·917	31	13·929	56	16·029	81	16·518
7	5·582	32	14·084	57	16·065	82	16·526
8	6·210	33	14·230	58	16·[illegible]99	83	16·534
9	6·802	34	14·368	59	16·131	84	16·542
10	7·360	35	14·498	60	16·161	85	16·549
11	7·887	36	14·621	61	16·190	86	16·556
12	8·384	37	14·737	62	16·217	87	16·562
13	8·853	38	14·846	63	16·242	88	16·568
14	9·295	39	14·949	64	16·266	89	16·573
15	9·712	40	15·046	65	16·289	90	16·579
16	10·106	41	15·138	66	16·310	91	16·584
17	10·477	42	15·225	67	16·331	92	16·588
18	10·828	43	15·306	68	16·350	93	16·593
19	11·158	44	15·383	69	16·368	94	16·597
20	11·470	45	15·456	70	16·3[illegible]5	95	16·601
21	11·764	46	15·524	71	16·401	96	16·6[illegible]5
22	12·042	47	15·589	72	16·416	97	16·608
23	12·303	48	15·650	73	16·430	98	16·611
24	12·550	49	15·708	74	16·443	99	16·615
25	12·783	50	15·762	75	16·456	100	16·6[illegible]8

TABLE IV.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

7 per Cent.

Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·935	26	11·826	51	13·832	76	14·202
2	1·808	27	11·987	52	13·862	77	14·208
3	2·624	28	12·137	53	13 890	78	14·213
4	3·387	29	12·278	54	13·916	79	14·218
5	4·100	30	12·409	55	13·940	80	14·222
6	4·767	31	12·532	56	13·963	81	14·226
7	5·389	32	12 647	57	13·984	82	14·230
8	5·971	33	12·754	58	14·003	83	14·234
9	6·515	34	12·854	59	14·022	84	14·237
10	7·024	35	12·948	60	14·039	85	14·240
11	7·499	36	13·035	61	14·055	86	14·243
12	7·943	37	13·117	62	14·070	87	14·246
13	8·358	38	13·193	63	14·084	88	14·249
14	8·745	39	13 265	64	14·098	89	14·251
15	9·108	40	13 332	65	14·110	90	14·253
16	9·447	41	13·394	66	14·121	91	14·255
17	9·763	42	13·452	67	14·132	92	14·257
18	10·059	43	13·507	68	14·142	93	14·259
19	10·336	44	13·558	69	14·152	94	14·261
20	10·594	45	13 606	70	14·160	95	14·263
21	10·836	46	13·650	71	14·169	96	14·264
22	11·061	47	13 692	72	14·176	97	14·266
23	11·272	48	13·730	73	14·183	98	14·267
24	11·469	49	13·767	74	14·190	99	14·268
25	11·654	50	13·801	75	14·196	100	14·269

8 per Cent.

Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·926	26	10·810	51	12·253	76	12·464
2	1·783	27	10·935	52	12·272	77	12·467
3	2·577	28	11·051	53	12·288	78	12·469
4	3 312	29	11·158	54	12·304	79	12·471
5	3·993	30	11·258	55	12·319	80	12·474
6	4·623	31	11·350	56	12·332	81	12·476
7	5·206	32	11·435	57	12·344	82	12·477
8	5·747	33	11·514	58	12·356	83	12·479
9	6·247	34	11·587	59	12·367	84	12·481
10	6·710	35	11·655	60	12·377	85	12·482
11	7·139	36	11·717	61	12·386	86	12·483
12	7·536	37	11·775	62	12·394	87	12·485
13	7·904	38	11·829	63	12·402	88	12·486
14	8·244	39	11·879	64	12·409	89	12·487
15	8·559	40	11·925	65	12·416	90	12·488
16	8·851	41	11·967	66	12·422	91	12·489
17	9·122	42	12·007	67	12·428	92	12·489
18	9·372	43	12·043	68	12·433	93	12·490
19	9·604	44	12 077	69	12·438	94	12·491
20	9·818	45	12·108	70	12·443	95	12·492
21	10·017	46	12·137	71	12·447	96	12·492
22	10·201	47	12·164	72	12·451	97	12·493
23	10·3[illegible]1	48	12·189	73	12·455	98	12·493
24	10·529	49	12·212	74	12·458	99	12·494
25	10 675	50	12·233	75	12·461	100	12·494

TABLE IV.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continu d.*

9 per Cent.								10 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·917	26	9·929	51	10 974	76	11·095	1	·909	26	9·161	51	9·923	76	9 993
2	1·759	27	10·027	52	10·985	77	11·097	2	1·736	27	9·237	52	9·930	77	9·994
3	2·531	28	10·116	53	10·996	78	11·098	3	2·487	28	9 307	53	9·936	78	9·994
4	3 240	29	10·198	54	11·005	79	11·099	4	3·170	29	9 370	54	9·942	79	9·995
5	3 890	30	10·273	55	11·014	80	11·100	5	3·791	30	9·427	55	9·947	80	9·995
6	4·486	31	10 343	56	11·022	81	11·101	6	4·355	31	9·479	56	9·952	81	9·996
7	5·033	32	10·406	57	11·029	82	11·102	7	4·868	32	9·526	57	9·956	82	9 996
8	5·535	33	10·464	58	11·036	83	11·102	8	5·335	33	9·569	58	9·960	83	9·996
9	5·995	34	10·518	59	11·042	84	11·103	9	5·759	34	9·609	59	9·964	84	9·997
10	6·418	35	10·567	60	11·048	85	11·104	10	6·145	35	9 644	60	9 967	85	9·997
11	6·805	36	10·612	61	11·053	86	11·104	11	6·495	36	9 677	61	9·970	86	9·997
12	7·161	37	10·653	62	11·058	87	11·105	12	6 814	37	9·706	62	9·973	87	9·997
13	7·487	38	10 691	63	11·062	88	11·106	13	7·103	38	9·733	63	9·975	88	9·998
14	7·786	39	10·726	64	11·066	89	11·106	14	7·367	39	9 757	64	9 978	89	9·998
15	8·061	40	10·757	65	11·070	90	11·106	15	7·606	40	9·779	65	9 980	90	9·998
16	8 313	41	10·787	66	11·074	91	11·107	16	7·824	41	9·799	66	9 982	91	9 998
17	8·544	42	10·813	67	11·077	92	11·107	17	8·022	42	9 817	67	9 983	92	9·998
18	8·756	43	10·838	68	11·079	93	11·107	18	8·201	43	9 834	68	9·985	93	9 999
19	8·950	44	10 861	69	11·082	94	11·108	19	8·365	44	9 849	69	9·986	94	9·999
20	9·129	45	10·881	70	11·084	95	11·108	20	8 514	45	9 863	70	9·987	95	9 999
21	9·292	46	10·900	71	11·087	96	11·108	21	8 649	46	9 875	71	9·988	96	9 999
22	9·442	47	10 918	72	11·089	97	11·109	22	8·772	47	8 887	72	9·990	97	9·999
23	9·580	48	10·934	73	11·091	98	11·109	23	8·883	48	9 897	73	9·990	98	9·999
24	9·707	49	10 948	74	11·092	99	11·109	24	8·985	49	9·906	74	9·991	99	9·999
25	9·823	50	10 962	75	11·094	100	11·109	25	9 077	50	9 915	75	9 992	100	9 999

Table V.

The Present Value of One Pound per Annum payable for a Term of Years

As in Table IV., except that the Reserved Fund is supposed to be invested at the uniform rate of 3 per cent. interest.

Example.—An Estate held for 20 years is worth at the present time 11·4658 years' purchase if the purchaser expects 5 per cent. for his money, and intends to invest the Reserved Sum at 3 per cent.

Interest 3½ per Cent.							
Years.	Value.	Years.	Value.	Years.	Value.	Years.	Value.
1	·9662	26	16·410	51	22·971	76	25·941
2	1·8953	27	16·786	52	23·139	77	26·019
3	2·7892	28	17·155	53	23·302	78	26·095
4	3·6493	29	17·509	54	23·460	79	26·168
5	4·4772	30	17·851	55	23·613	80	26·239
6	5·2743	31	18·182	56	23·762	81	26·307
7	6·0421	32	18·502	57	23·906	82	26·374
8	6·7817	33	18·813	58	24·045	83	26·439
9	7·4943	34	19·112	59	24·180	84	26·502
10	8·1812	35	19·403	60	24·311	85	26·563
11	8·8435	36	19·684	61	24·438	86	26·622
12	9·4821	37	19·955	62	24·562	87	26·679
13	10·0980	38	20·219	63	24·681	88	26·735
14	10·6922	39	20·473	64	24·797	89	26·789
15	11·2655	40	20·720	65	24·909	90	26·842
16	11·8188	41	20·959	66	25·018	91	26·893
17	12·3529	42	21·190	67	25·124	92	26·942
18	12·8685	43	21·414	68	25·226	93	26·990
19	13·366[illegible]	44	21·631	69	25·325	94	27·036
20	13·8474	45	21·841	70	25·422	95	27·081
21	14·3119	46	22·045	71	25·515	96	27·125
22	14·7608	47	22·242	72	25·606	97	27·168
23	15·1943	48	22·433	73	25·693	98	27·209
24	15·6135	49	22·618	74	25·778	99	27·250
25	16·0185	50	22·797	75	25·861	100	27·288

TABLE V.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued*

4 per Cent.								4½ per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·9615	26	15·166	51	20·604	76	22·963	1	·9569	26	14·097	51	18·680	76	20·598
2	1·8775	27	15·488	52	20·739	77	23·024	2	1·8601	27	14·375	52	18·787	77	20·647
3	2·7508	28	15·799	53	20·870	78	23·083	3	2·7135	28	14·643	53	18·898	78	20·694
4	3·5839	29	16·099	54	20·997	79	23·140	4	3·5208	29	14·900	54	19·002	79	20·740
5	4·3791	30	16·388	55	21·120	80	23·196	5	4·2853	30	15·147	55	19·103	80	20·785
6	5·1388	31	16·667	56	21·238	81	23·249	6	5·0101	31	15·385	56	19·200	81	20·828
7	5·8649	32	16·936	57	21·353	82	23·301	7	5·6578	32	15·614	57	19·293	82	20·870
8	6·5593	33	17·195	58	21·465	83	23·352	8	6·3510	33	15·834	58	19·384	83	20·911
9	7·2237	34	17·445	59	21·572	84	23·401	9	6·9719	34	16·046	59	19·472	84	20·948
10	7·8597	35	17·686	60	21·676	85	23·448	10	7·5626	35	16·259	60	19·557	85	20·9[illegible]8
11	8·4690	36	17·920	61	21·777	86	23·495	11	8·1250	36	16·446	61	19·639	86	21·025
12	9·0528	37	18·145	62	21·875	87	23·539	12	8·6609	37	16·636	62	19·719	87	21·061
13	9·6126	38	18·362	63	21·970	88	23·583	13	9·1718	38	16·818	63	19·795	88	21·095
14	10·1436	39	18·572	64	22·062	89	23·625	14	9·6594	39	16·994	64	19·870	89	21·129
15	10·6648	40	18·775	65	22·150	90	23·666	15	10·1249	40	17·164	65	19·942	90	21·162
16	11·1594	41	18·971	66	22·237	91	23·705	16	10·5696	41	17·327	66	20·012	91	21·193
17	11·6343	42	19·160	67	22·32[illegible]	92	23·743	17	10·9947	42	17·485	67	20·079	92	21·224
18	12·0906	43	19·343	68	22·401	93	23·781	18	11·4038	43	17·637	68	20·144	93	21·254
19	12·5291	44	19·520	69	22·479	94	23·817	19	11·7905	44	17·784	69	20·208	94	21·281
20	12·9507	45	19·691	70	22·555	95	23·852	20	12·1631	45	17·925	70	20·269	95	21·310
21	13·3562	46	19·856	71	22·623	96	23·886	21	12·5201	46	18·063	71	20·328	96	21·337
22	13·7462	47	20·016	72	22·699	97	23·919	22	12·8622	47	18·195	72	20·386	97	21·364
23	14·1215	48	20·170	73	22·768	98	23·950	23	13·1902	48	18·322	73	20·441	98	21·389
24	14·4828	49	20·320	74	22·835	99	23·981	24	13·5049	49	18·446	74	20·495	99	21·414
25	14·8307	50	20·465	75	22·900	100	24·011	25	13·8068	50	18·565	75	20·568	100	21·438

TABLE V.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

5 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·9524	26	13·169	51	17·084	76	18·675
2	1·8429	27	13 411	52	17·177	77	18·715
3	2·6772	28	13·644	53	17·267	78	18·754
4	3·4598	29	13 867	54	17·353	79	18·792
5	4·1954	30	14·081	55	17·437	80	18·828
6	4·8876	31	14·286	56	17·518	81	18·864
7	5·5400	32	14·483	57	17·596	82	18·898
8	6·1555	33	14·672	58	17·671	83	18·931
9	6·7370	34	14·854	59	17·744	84	18·963
10	7·2870	35	15·029	60	17·815	85	18 995
11	7·8078	36	15·197	61	17·883	86	19·025
12	8·3014	37	15·358	62	17·949	87	19·054
13	8·7696	38	15·514	63	18·013	88	19·083
14	9·2144	39	15·663	64	18·074	89	19·110
15	9·6370	40	15·807	65	18·134	90	19·137
16	10·0391	41	15·946	66	18·191	91	19·164
17	10·4218	42	16·079	67	18·247	92	19·188
18	10·7865	43	16·208	68	18·301	93	19·212
19	11·1340	44	16·332	69	18·353	94	19·236
20	11·4658	45	16·451	70	18·404	95	19·258
21	11·7825	46	16·567	71	18·453	96	19·281
22	12·0850	47	16·678	72	18·500	97	19·302
23	12·3741	48	16·785	73	18·546	98	19·323
24	12·6506	49	16·888	74	18·590	99	19·343
25	12 9152	50	16·988	75	18·633	100	19·362

6 per Cent.							
Yrs.	Value.	Yrs.	Value	Yrs.	Value.	Yrs.	Value.
1	·9434	26	11·636	51	14·591	76	15·736
2	1·8096	27	11·826	52	14 659	77	15·765
3	2 6074	28	12·006	53	14·724	78	15·792
4	3·3442	29	12·178	54	14·787	79	15·819
5	4 0265	30	12 343	55	14·848	80	15·845
6	4·6699	31	12·500	56	14·907	81	15·870
7	5·2492	32	12·651	57	14·963	82	15·894
8	5·7986	33	12·795	58	15·018	83	15·918
9	6·3118	34	12·933	59	15·070	84	15·941
10	6·7920	35	13·065	60	15·121	85	15·962
11	7·2423	36	13·192	61	15·170	86	15·984
12	7·6651	37	13·3[illegible]4	62	15·218	87	16·005
13	8·0626	38	13·430	63	15·263	88	16·025
14	8·4370	39	13·542	64	15·308	89	16·044
15	8·7899	40	13·650	65	15·350	90	16·063
16	9·1232	41	13·753	66	15 391	91	16·081
17	9·4381	42	13·852	67	15·431	92	16·099
18	9·7362	43	13·917	68	15·470	93	16·116
19	10·0187	44	14·039	69	15·507	94	16·132
20	10·2864	45	14·127	70	15·543	95	16·148
21	10·5405	46	14·212	71	15·578	96	16·164
22	10·7820	47	14·294	72	15·612	97	16·179
23	11·0115	48	14·372	73	15·644	48	16·194
24	11·2300	49	14·448	74	15·676	99	16·208
25	11·4380	50	14·521	75	15·706	100	16·222

Table V.—The Present Value of One Pound per Annum, Etc.—*continued.*

7 per Cent.								8 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·9346	26	10·423	51	12·733	76	13·596	1	·9259	26	9·439	51	11·295	76	11·969
2	1·7774	27	10·575	52	12·785	77	13·618	2	1·7464	27	9·561	52	11·336	77	11·986
3	2·5411	26	10·719	53	12·835	78	13·638	3	2·4781	28	9·681	53	11·375	78	12·002
4	3·2360	29	10·856	54	12·882	79	13·658	4	3·1345	29	9·793	54	11·412	79	12·017
5	3·8706	30	10·987	55	12·928	80	13·678	5	3·7264	30	9·899	55	11·448	80	12·032
6	4·4524	31	11·111	56	12·973	81	13·696	6	4·2626	31	10·000	56	11·483	81	12·046
7	4·9874	32	11·230	57	13·015	82	13·714	7	4·7505	32	10·096	57	11·517	82	12·060
8	5·4808	33	11·343	58	13·057	83	13·732	8	5·1960	33	10·188	58	11·549	83	12·074
9	5·9370	34	11·452	59	13·096	84	13·749	9	5·6043	34	10·275	59	11·580	84	12·087
10	6·3601	35	11·555	60	13·135	85	13·765	10	5·9798	35	10·358	60	11·610	85	12·100
11	6·7532	36	11·654	61	13·172	86	13·781	11	6·3260	36	10·438	61	11·639	86	12·112
12	7·1194	37	11·748	62	13·208	87	13·796	12	6·6462	37	10·514	62	11·667	87	12·124
13	7·4610	38	11·840	63	13·242	88	13·811	13	6·9430	38	10·587	63	11·694	88	12·135
14	7·7805	39	11·927	64	13·275	89	13·826	14	7·2189	39	10·656	64	11·720	89	12·146
15	8·0797	40	12·010	65	13·307	90	13·840	15	7·4757	40	10·722	65	11·745	90	12·157
16	8·3604	41	12·090	66	13·337	91	13·854	16	7·7154	41	10·786	66	11·769	91	12·168
17	8·6242	42	12·167	67	13·368	92	13·866	17	7·9395	42	10·847	67	11·792	92	12·178
18	8·8724	43	12·240	68	13·397	93	13·879	18	8·1494	43	10·905	68	11·815	93	12·188
19	9·1063	44	12·311	69	13·425	94	13·891	19	8·3463	44	10·961	69	11·836	94	12·197
20	9·3 70	45	12·379	70	13·452	95	13·903	20	8·53 3	45	11·015	70	11·857	95	12·206
21	9·5354	46	12·444	71	13·478	96	13·9 5	21	8·7053	46	11·067	71	11·878	96	12·215
22	9·73 6	47	12·506	72	13·504	97	13·926	22	8·8694	47	11·116	72	11·897	97	12·224
23	9·9 93	48	12·566	73	13·528	98	13·937	23	9·0241	48	11·163	73	11·916	98	12·232
24	10·0962	49	12·624	74	13·552	99	13·947	24	9·1703	49	11·209	74	11·934	99	12·240
25	10·2640	50	12·6 0	75	13·574	100	13·957	25	9·3086	50	11·253	75	11·952	100	12·248

TABLE V.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

9 per Cent.								10 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·9174	26	8·625	51	10·149	76	10·690	1	·9091	26	7·940	51	9·214	76	9·657
2	1·7164	27	8·729	52	10·182	77	10·703	2	1·6874	27	8·028	52	9·241	77	9·668
3	2·4182	28	8·827	53	10·213	78	10·716	3	2·3611	28	8·111	53	9·267	78	9·678
4	3·0393	29	8·919	54	10·243	79	10·728	4	2·9496	29	8·189	54	9·291	79	9·689
5	3·5925	30	9·007	55	10·272	80	10·740	5	3·4680	30	8·263	55	9·315	80	9·698
6	4·0883	31	9·091	56	10·300	81	10·751	6	3·92[illegible]9	31	8·333	56	9·338	81	9·708
7	4·5350	32	9·170	57	10·327	82	10·762	7	4·3383	32	8·400	57	9·361	82	9·717
8	4·9393	33	9·246	58	10·353	83	10·773	8	4·7069	33	8·463	58	9·382	83	9·725
9	5·3069	34	9·318	59	10·378	84	10·784	9	5·0395	34	8·524	59	9·402	84	9·734
10	5·6424	35	9·386	60	10·402	85	10·794	10	5·3410	35	8·581	60	9·422	85	9·742
11	5·9497	36	9·451	61	10·425	86	10·804	11	5·6156	36	8·635	61	9·441	86	9·750
12	6·2320	37	9·514	62	10·448	87	10·813	12	5·8664	37	8·687	62	9·459	87	9·758
13	6·4922	38	9·573	63	10·469	88	10·822	13	6·0965	38	8·737	63	9·477	88	9·765
14	6·7328	39	9·630	64	10·490	89	10·831	14	6·3082	39	8·784	64	9·494	89	9·773
15	6·9557	40	9·684	65	10·510	90	10·839	15	6·5034	40	8·829	65	9·511	90	9·779
16	7·1628	41	9·736	66	10·530	91	10·848	16	6·6840	41	8·872	66	9·526	91	9·786
17	7·3555	42	9·786	67	10·548	92	10·856	17	6·8515	42	8·913	67	9·542	92	9·793
18	7·5353	43	9·833	68	10·566	93	10·864	18	7·0073	43	8·953	68	9·556	93	9·799
19	7·7033	44	9·8[illegible]8	69	10·584	94	10·871	19	7·1524	44	8·990	69	9·571	94	9·805
20	7·8607	45	9·922	70	10·600	95	10·878	20	7·2878	45	9·026	70	9·584	95	9·811
21	8·0082	46	9·964	71	10·617	96	10·885	21	7·4[illegible]44	46	9·061	71	9·598	96	9·817
22	8·1468	47	10·004	72	10·632	97	10·892	22	7·5331	47	9·094	72	9·610	97	9·822
23	8·2772	48	10·042	73	10·647	98	10·899	23	7·6444	48	9·126	73	9·623	98	9·828
24	8·4000	49	10·079	74	10·662	99	10·905	24	7·7491	49	9·156	74	9·635	99	9·833
25	8·5158	50	10·115	75	10·676	100	10·911	25	7·8476	50	9·186	75	9·646	100	9·838

Table VI.

The Present Value of the Reversion of One Pound at the End of any Number of Years.

Example.—A Legacy of £100 to be paid in 20 years hence is worth at the present time at 5 per cent. only £37·69.

Interest 2 per Cent.							
Years.	Value.	Years.	Value.	Years.	Value.	Years.	Value
1	·9804	26	·5976	51	·3642	76	·2220
2	·9612	27	·58 9	52	·3571	77	·2177
3	·9423	28	·5744	53	·3501	78	·2134
4	·9239	29	·5631	54	·3432	79	·2092
5	·9057	30	·5521	55	·3365	80	·2051
6	·8880	31	·5412	56	·3299	81	·2011
7	·8706	32	·5306	57	·3234	82	·1971
8	·8535	33	·5202	58	·3171	83	·1933
9	·8368	34	·5100	59	·3109	84	·1895
10	·8203	35	·5000	60	·3048	85	·1858
11	·8043	36	·4902	61	·2988	86	·1821
12	·7885	37	·4806	62	·2930	87	·1786
13	·7730	38	·4712	63	·2872	88	·1751
14	·7579	39	·4620	64	·2816	89	·1716
15	·7430	40	·4529	65	·2761	90	·1683
16	·7285	41	·4440	66	·2706	91	·1650
17	·7142	42	·4353	67	·2653	92	·1617
18	·7002	43	·4268	68	·2601	93	·1 86
19	·6864	44	·4184	69	·2550	94	·1554
20	·6730	45	·4102	70	·2500	95	·1524
21	·6598	46	·4022	71	·2451	96	·1494
22	·6468	47	·3943	72	·2403	97	·1465
23	·6342	48	·3865	73	·2356	98	·1436
24	·6217	49	·3790	74	·2310	99	·1408
25	·6095	50	·3715	75	·2265	100	·1380

TABLE VI.—PRESENT VALUE OF THE REVERSION OF ONE POUND, ETC.—*contd.*

2½ per Cent.								3 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·9756	26	·5262	51	·2838	76	·1531	1	·9709	26	·4637	51	·2215	76	·1058
2	·9518	27	·5134	52	·2769	77	·1494	2	·9426	27	·4502	52	·2150	77	·1027
3	·9286	28	·5009	53	·2702	78	·1457	3	·9151	28	·4371	53	·2088	78	·0997
4	·9060	29	·4887	54	·263[illegible]	79	·1422	4	·8885	29	·4243	54	·2027	79	·0968
5	·8839	30	·4767	55	·2572	80	·1387	5	·8626	30	·4120	55	·1968	80	·0940
6	·8623	31	·4651	56	·2509	81	·1353	6	·8375	31	·4000	56	·1910	81	·0912
7	·8413	32	·4538	57	·2448	82	·1320	7	·8131	32	·3883	57	·1855	82	·0886
8	·8207	33	·4427	58	·2388	83	·1288	8	·7894	33	·3770	58	·1801	83	·0860
9	·8007	34	·4319	59	·2330	84	·1257	9	·7664	34	·3660	59	·1748	84	·0835
10	·7812	35	·4214	60	·2273	85	·1226	10	·7441	35	·3554	60	·1697	85	·0811
11	·7621	36	·4111	61	·2217	86	·1196	11	·7224	36	·3450	61	·1648	86	·0787
12	·7436	37	·4011	62	·2163	87	·1167	12	·7014	37	·3350	62	·1600	87	·0764
13	·7254	38	·3913	63	·2111	88	·1138	13	·6810	38	·3252	63	·1553	88	·0742
14	·7077	39	·3817	64	·2059	89	·1111	14	·6611	39	·3158	64	·1508	89	·0720
15	·6905	40	·3724	65	·2009	90	·1084	15	·6419	40	·3066	65	·1464	90	·0699
16	·6736	41	·3634	66	·1960	91	·1057	16	·6232	41	·2976	66	·1421	91	·0679
17	·6572	42	·3545	67	·1912	92	·1031	17	·6050	42	·2890	67	·1380	92	·0659
18	·6412	43	·3458	68	·1865	93	·1006	18	·5874	43	·2805	68	·1340	93	·0640
19	·6255	44	·3374	69	·1820	94	·0982	19	·5703	44	·2724	69	·1301	94	·0621
20	·6103	45	·3292	70	·1776	95	·0958	20	·5537	45	·2644	70	·1263	95	·0603
21	·5954	46	·3211	71	·1732	96	·0934	21	·5375	46	·2567	71	·1226	96	·0586
22	·5809	47	·3133	72	·1690	97	·0912	22	·5219	47	·2493	72	·1190	97	·0569
23	·5667	48	·3057	73	·1649	98	·0889	23	·5067	48	·2420	73	·1156	98	·0552
24	·5529	49	·2982	74	·1609	99	·0868	24	·4919	49	·2350	74	·1122	99	·0536
25	·5394	50	·2909	75	·1569	100	·0846	25	·4776	50	·2281	75	·1089	100	·0520

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TABLE VI.—PRESENT VALUE OF THE REVERSION OF ONE POUND, ETC.—*contd.*

3½ per Cent.								4 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·9662	26	·4088	51	·1730	76	·0732	1	·9615	26	·3607	51	·1353	76	·0508
2	·9335	27	·3950	52	·1671	77	·0707	2	·9246	27	·3468	52	·1301	77	·0488
2	·9019	28	·3817	53	·1615	78	·0683	3	·8890	28	·3335	53	·1251	78	·0469
4	·8714	29	·3687	54	·1560	79	·0660	4	·8548	29	·3207	54	·1203	79	·0451
5	·8420	30	·3563	55	·1508	80	·0638	5	·8219	30	·3083	55	·1157	80	·0434
6	·8135	31	·3442	56	·1457	81	·0616	6	·7903	31	·2965	56	·1112	81	·0417
7	·7860	32	·3326	57	·1407	82	·0596	7	·7599	32	·2851	57	·1069	82	·0401
8	·7594	33	·3213	58	·1360	83	·0575	8	·7307	33	·2741	58	·1028	83	·0386
9	·7337	34	·3105	59	·1314	84	·0556	9	·7026	34	·2636	59	·0989	84	·0371
10	·7089	35	·3000	60	·1269	85	·0537	10	·6756	35	·2534	60	·0951	85	·0357
11	·6849	36	·2898	61	·1226	86	·0519	11	·6496	36	·2437	61	·0914	86	·0343
12	·6618	37	·2800	62	·1185	87	·0501	12	·6246	37	·2343	62	·0879	87	·0330
13	·6394	38	·2706	63	·1145	88	·0484	13	·6006	38	·2253	63	·0845	88	·0317
14	·6178	39	·2614	64	·1106	89	·0468	14	·5775	39	·2166	64	·0813	89	·0305
15	·5969	40	·2526	65	·1069	90	·0452	15	·5553	40	·2083	65	·0781	90	·0293
16	·5767	41	·2440	66	·1033	91	·0437	16	·5339	41	·2003	66	·0751	91	·0282
17	·5572	42	·2358	67	·0998	92	·0422	17	·5134	42	·1926	67	·0722	92	·0271
18	·5384	43	·2278	68	·0964	93	·0408	18	·4936	43	·1852	68	·0695	93	·0261
19	·5202	44	·2201	69	·0931	94	·0394	19	·4746	44	·1780	69	·0668	94	·0251
20	·5026	45	·2127	70	·0900	95	·0381	20	·4564	45	·1712	70	·0642	95	·0241
21	·4856	46	·2055	71	·0869	96	·0368	21	·4388	46	·1646	71	·0617	96	·0232
22	·4692	47	·1985	72	·0840	97	·0355	22	·4220	47	·1583	72	·0594	97	·0223
23	·4533	48	·1918	73	·0812	98	·0343	23	·4057	48	·1522	73	·0571	98	·0214
24	·4380	49	·1853	74	·0784	99	·0332	24	·3901	49	·1463	74	·0549	99	·0206
25	·4231	50	·1791	75	·0758	100	·0321	25	·3751	50	·1407	75	·0528	100	·0198

Table VI.—Present Value of the Reversion of One Pound, Etc.—*contd*

4½ per Cent.								5 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·9569	26	·3184	51	·1059	76	·0353	1	·9524	26	·2812	51	·0831	76	·0245
2	·9157	27	·3047	52	·1014	77	·0337	2	·9070	27	·2678	52	·0791	77	·0234
3	·8763	28	·2916	53	·0970	78	·0323	3	·8638	28	·2551	53	·0753	78	·0222
4	·8386	29	·2790	54	·0928	79	·0309	4	·8227	29	·2429	54	·07[illegible]7	79	·0212
5	·8025	30	·2670	55	·0888	80	·0296	5	·7835	30	·2314	55	·0683	80	·0202
6	·7679	31	·2555	56	·0850	81	·0283	6	·7462	31	·2204	56	·0651	81	·0192
7	·7348	32	·2445	57	·0814	82	·0271	7	·7107	32	·2099	57	·0620	82	·0183
8	·7032	33	·23[illegible]0	58	·0779	83	·0259	8	·67[illegible]8	33	·1999	58	·0590	83	·0174
9	·6729	34	·2239	59	·0745	84	·02[illegible]8	9	·6446	34	·1904	59	·0562	84	·0166
10	·6439	35	·2143	60	·07[illegible]3	85	·0237	10	·6139	35	·1813	60	·0535	85	·0158
11	·6162	36	·2050	61	·0682	86	·0227	11	·5847	36	·1727	61	·0510	86	·0151
12	·5897	37	·1962	62	·0653	87	·0217	12	·5568	37	·1644	62	·0486	87	·0143
13	·5643	38	·1878	63	·0625	88	·0208	13	·5303	38	·1566	63	·0462	88	·0137
14	·5400	39	·1797	64	·0598	89	·0199	14	·5051	39	·1491	64	·0440	89	·0130
15	·5167	40	·1719	65	·0572	90	·0190	15	·4810	40	·1420	65	·0419	90	·01[illegible]4
16	·4945	41	·1645	66	·0547	91	·0182	16	·4581	41	·1353	66	·0399	91	·0118
17	·4732	42	·1574	67	·0524	92	·0174	17	·4363	42	·1288	67	·0389	92	·0112
18	·4528	43	·1507	68	·0501	93	·0167	18	·4155	43	·1227	68	·0362	93	·0107
19	·4333	44	·1442	69	·0480	94	·0160	19	·3957	44	·1169	69	·0345	94	·0102
20	·4146	45	·1380	70	·0459	95	·0153	20	·3769	45	·1113	70	·0329	95	·0097
21	·3968	46	·1320	71	·0439	96	·0146	21	·3589	46	·106[illegible]	71	·0313	96	·0092
22	·3797	47	·1263	72	·0420	97	·0140	22	·3418	47	·1009	72	·0298	97	·0088
23	·3634	48	·1209	73	·0402	98	·0134	23	·3256	48	·0961	73	·0284	98	·0084
24	·3477	49	·1157	74	·0385	99	·0128	24	·3101	49	·0916	74	·0270	99	·0080
25	·3327	50	·1107	75	·0268	100	·0123	25	·2953	50	·0872	75	·0258	100	·0076

TABLE VI.—PRESENT VALUE OF THE REVERSION OF ONE POUND, ETC.—*contd.*

6 per Cent.								7 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·9434	26	·2198	51	·0512	76	·0119	1	·9346	26	·1722	51	·0317	76	·0058
2	·8900	27	·2074	52	·0483	77	·0113	2	·8734	27	·1609	52	·0297	77	·0055
3	·8396	28	·1956	53	·0456	78	·0106	3	·8163	28	·1504	53	·0277	78	·0051
4	·7921	29	·1846	54	·0430	79	·0100	4	·7629	29	·1406	54	·0259	79	·0048
5	·7473	30	·1741	55	·0406	80	·0095	5	·7130	30	·1314	55	·0242	80	·0045
6	·7050	31	·1643	56	·0383	81	·0089	6	·6663	31	·1228	56	·0226	81	·0042
7	·6651	32	·1550	57	·0361	82	·0084	7	·6227	32	·1147	57	·0211	82	·0039
8	·6274	33	·1462	58	·0341	83	·0079	8	·5820	33	·1072	58	·0198	83	·0036
9	·5919	34	·1379	59	·0321	84	·0075	9	·5439	34	·1002	59	·0185	84	·0034
10	·5584	35	·1301	60	·0303	85	·0071	10	·5084	35	·0937	60	·0173	85	·0032
11	·5268	36	·1227	61	·0286	86	·0067	11	·4751	36	·0875	61	·0161	86	·0030
12	·4970	37	·1158	62	·0270	87	·0063	12	·4440	37	·0818	62	·0151	87	·0028
13	·4688	38	·1092	63	·0255	88	·0059	13	·4150	38	·0765	63	·0141	88	·0026
14	·4423	39	·1031	64	·0240	89	·0056	14	·3878	39	·0715	64	·0132	89	·0024
15	·4173	40	·0972	65	·0227	90	·0053	15	·3624	40	·0668	65	·0123	90	·0023
16	·3936	41	·0917	66	·0214	91	·0050	16	·3387	41	·0624	66	·0115	91	·0021
17	·3714	52	·0865	67	·0202	92	·0047	17	·3166	42	·0583	67	·0107	92	·0020
18	·3503	43	·0816	68	·0190	93	·0044	18	·2959	43	·0545	68	·0100	93	·0019
19	·3305	44	·0770	69	·0179	94	·0042	19	·2765	44	·0509	69	·0094	94	·0017
20	·3118	45	·0727	70	·0169	95	·0039	20	·2584	45	·0476	70	·0088	95	·0016
21	·2942	46	·0685	71	·0160	96	·0037	21	·2415	46	·0445	71	·0082	96	·0015
22	·2775	47	·0647	72	·0151	97	·0035	22	·2257	47	·0416	72	·0077	97	·0014
23	·2618	48	·0610	73	·0142	98	·0033	23	·2109	48	·0389	73	·0072	98	·0013
24	·2470	49	·0575	74	·0134	99	·0031	24	·1971	49	·0363	74	·0067	99	·0012
25	·2330	50	·0543	75	·0127	100	·0030	25	·1842	50	·0339	75	·0063	100	·0012

TABLE VI.—PRESENT VALUE OF THE REVERSION OF ONE POUND, ETC.—*contd.*

8 per Cent.								9 per Cent.							
Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.	Yrs.	Value.
1	·9259	26	·1352	51	·0197	76	·0029	1	·9174	26	·1064	51	·0123	76	·0014
2	·8573	27	·1252	52	·0183	77	·0027	2	·8417	27	·0976	52	·0113	77	·0013
3	·7938	28	·1159	53	·0169	78	·0025	3	·7722	28	·0895	53	·0104	78	·0012
4	·7350	29	·1073	54	·0157	79	·0023	4	·7084	29	·0822	54	·0095	79	·0011
5	·6806	30	·0994	55	·0145	80	·0021	5	·6499	30	·0754	55	·0087	80	·0010
6	·6302	31	·0920	56	·0134	81	·0020	6	·5963	31	·0691	56	·0080	81	·0009
7	·5835	32	·0852	57	·0124	82	·0018	7	·5470	32	·0634	57	·0074	82	·0009
8	·5403	33	·0789	58	·0115	83	·0017	8	·5019	33	·0582	58	·0067	83	·0008
9	·5002	34	·0730	59	·0107	84	·0016	9	·4604	34	·0534	59	·0062	84	·0007
10	·4632	35	·0676	60	·0099	85	·0014	10	·4224	35	·0490	60	·0057	85	·0007
11	·42 9	36	·0626	61	·0091	86	·0013	11	·3875	36	·0449	61	·0052	86	·0006
12	·3971	37	·0580	62	·0085	87	·0012	12	·3555	37	·0412	62	·0048	87	·0006
13	·3677	38	·0537	63	·0078	88	·0011	13	·3262	38	·0378	63	·0044	88	·0005
14	·3405	39	·0497	64	·0073	89	·0011	14	·2992	39	·0347	64	·0040	89	·0005
15	·3152	40	·0460	65	·0067	90	·0010	15	·2745	40	·0318	65	·0037	90	·0004
16	·2919	41	·0426	66	·0062	91	·0009	16	·2519	41	·0292	66	·0034	91	·0004
17	·2703	42	·0395	67	·0058	92	·0008	17	·2311	42	·0268	67	·0031	92	·0004
18	·2502	43	·0365	68	·0053	93	·0008	18	·2120	43	·0246	68	·0029	93	·0003
19	·2317	44	·0338	69	·0049	94	·0007	19	·1945	44	·0226	69	·0026	94	·0003
20	·2145	45	·0313	70	·0046	95	·0007	20	·1784	45	·0207	70	·0024	95	·0003
21	·1987	46	·0290	71	·0042	96	·0006	21	·1637	46	·0190	71	·0022	96	·0003
22	·1839	47	·0269	72	·0039	97	·0006	22	·1502	47	·0174	72	·0020	97	·0002
23	·1703	48	·0249	73	·0036	98	·0005	23	·1378	49	·0160	73	·0019	98	·0002
24	·1577	49	·0230	74	·0034	99	·0005	24	·1264	49	·0147	74	·0017	99	·0002
25	·1460	50	·0213	75	·0031	100	·0005	25	·1160	50	·0134	75	·0016	100	·0002

Table VI.

The Present Value of the Reversion of One Pound, Etc.—*continued.*

10 per Cent.							
Years.	Value.	Years.	Value.	Years.	Value.	Years.	Value.
1	·9091	26	·0839	51	·0077	76	·0007
2	·8264	27	·0763	52	·0070	77	·0007
3	·7513	28	·0693	53	·0064	78	·0006
4	·6830	29	·0630	54	·0058	79	·0005
5	·6209	30	·0573	55	·0053	80	·0005
6	·5645	31	·0521	56	·0048	81	·0004
7	·5132	32	·0474	57	·0044	82	·0004
8	·4665	33	·0431	58	·0040	83	·0004
9	·4241	34	·0391	59	·0036	84	·0003
10	·3855	35	·0356	60	·0033	85	·0003
11	·3505	36	·0324	61	·0030	86	·0003
12	·3186	37	·0294	62	·0027	87	·0003
13	·2897	38	·0267	63	·0025	88	·0002
14	·2633	39	·0243	64	·0022	89	·0002
15	·2394	40	·0221	65	·0020	90	·0002
16	·2176	41	·0201	66	·0019	91	·0002
17	·1978	42	·0183	67	·0017	92	·0002
18	·1799	43	·0166	68	·0015	93	·0001
19	·1635	44	·0151	69	·0014	94	·0001
20	·1486	45	·0137	70	·0013	95	·0001
21	·1351	46	·0125	71	·0012	96	·0001
22	·1228	47	·0113	72	·0010	97	·0001
23	·1117	48	·0103	73	·0010	98	·0001
24	·1015	49	·0094	74	·0009	99	·0001
25	·0923	50	·0085	75	·0008	100	·0001

TABLE VII.

The Present Value of One Pound per Annum held on a Single Life, according to the Carlisle Table of Mortality.

Example:—An Estate, Lease, or Annuity, held during the Life of a Person aged 30, is worth at the present time 14·72 years' purchase, if the purchaser expects 5 per cent. for his money, and can Invest the Reserved Sum at the same rate.

Interest 3 per Cent.									
Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.
Birth	17·32	26	20·44	52	13·56	78	4·84
1	20·09	27	20·21	53	13·18	79	4·59
2	21·50	28	19·98	54	12·80	80	4·36
3	22·68	29	19·76	55	12·41	81	4·12
4	23·29	30	19·56	56	12·01	82	3·90
5	23·69	31	19·35	57	11·61	83	3·67
6	23·85	32	19·14	58	11·22	84	3·45
7	23·87	33	18·91	59	10·84	85	3·23
8	23·80	34	18·68	60	10·49	86	3·03
9	23·68	35	18·43	61	10·18	87	2·87
10	23·51	36	18·18	62	9·88	88	2·78
11	23·33	37	17·93	63	9·57	89	2·67
12	23·14	38	17·67	64	9·25	90	2·50
13	22·96	39	17·41	65	8·92	91	2·48
14	22·77	40	17·14	66	8·58	92	2·58
15	22·58	41	16·39	67	8·23	93	2·69
16	22·40	42	16·64	68	7·87	94	2·74
17	22·23	43	16·39	69	7·50	95	2·76
18	22·06	44	16·13	70	7·12	96	2·70
19	21·88	45	15·86	71	6·74	97	2·56
20	21·69	46	15·59	72	6·37	98	2·39
21	21·50	47	15·29	73	6·04	99	2·13
22	21·30	48	14·99	74	5·75	100	1·68
23	21·10	49	14·65	75	5·51	101	1·23
24	20·89	50	14·30	76	5·28	102	·77
25	20·67	51	13·93	77	5·06	103	·32

TABLE VII.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

3½ per Cent.								4 per Cent.							
Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.
Birth	15·67	26	18·87	52	12·88	78	4·73	Birth	14·28	26	17·49	52	12·26	78	4·62
1	18·17	27	18·67	53	12·54	79	4·49	1	16·55	27	17·32	53	11·95	79	4·39
2	19·46	28	18·48	54	12·19	80	4·27	2	17·73	28	17·15	54	11·63	80	4·18
3	20·53	29	18·29	55	11·83	81	4·03	3	18·72	29	17·00	55	11·30	81	3·95
4	21·09	30	18·12	56	11·47	82	3·82	4	19·23	30	16·85	56	10·97	82	3·75
5	21·48	31	17·95	57	11·10	83	3·60	5	19·59	31	16·71	57	10·63	83	3·53
6	21·63	32	17·77	58	10·74	84	3·39	6	19·75	32	16·55	58	10·29	84	3·33
7	21·67	33	17·58	59	10·39	85	3·17	7	19·79	33	16·39	59	9·96	85	3·12
8	21·62	34	17·38	60	10·06	86	2·98	8	19·76	34	16·22	60	9·66	86	2·93
9	21·53	35	17·17	61	9·78	87	2·82	9	19·69	35	16·04	61	9·40	87	2·78
10	21·39	36	16·95	62	9·49	88	2·73	10	19·58	36	15·86	62	9·14	88	2·68
11	21·24	37	16·73	63	9·21	89	2·62	11	19·46	37	15·67	63	8·87	89	2·58
12	21·09	38	16·51	64	8·91	90	2·46	12	19·33	38	15·47	64	8·59	90	2·42
13	20·94	39	16·28	65	8·60	91	2·44	13	19·21	39	15·27	65	8·31	91	2·40
14	20·79	40	16·05	66	8·29	92	2·53	14	19·08	40	15·07	66	8·01	92	2·49
15	20·63	41	15·83	67	7·96	93	2·64	15	18·96	41	14·88	67	7·70	93	2·60
16	20·49	42	15·62	68	7·62	94	2·69	16	18·84	42	14·69	68	7·38	94	2·65
17	20·35	43	15·40	69	7·27	95	2·72	17	18·72	43	14·51	69	7·05	95	2·67
18	20·21	44	15·17	70	6·91	96	2·67	18	18·61	44	14·31	70	6·71	96	2·63
19	20·06	45	14·94	71	6·54	97	2·53	19	18·49	45	14·10	71	6·36	97	2·49
20	19·91	46	14·70	72	6·19	98	2·36	20	18·36	46	13·89	72	6·03	98	2·33
21	19·76	47	14·44	73	5·88	99	2·11	21	18·23	47	13·66	73	5·72	99	2·09
22	19·59	48	14·17	74	5·60	100	1·67	22	18·09	48	13·42	74	5·46	100	1·65
23	19·42	49	13·87	75	5·37	101	1·22	23	17·95	49	13·15	75	5·24	101	1·21
24	19·24	50	13·55	76	5·15	102	·77	24	17·80	50	12·87	76	5·02	102	·76
25	19·06	51	13·22	77	4·94	103	·32	25	17·64	51	12·57	77	4·82	103	·32

TABLE VII.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

5 per Cent.								6 per Cent.							
Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value	Age.	Value.
Birth	12·03	26	15·19	52	11·15	78	4·42	Birth	10·44	26	13·37	52	10·21	78	4·24
1	13·99	27	15·07	53	10·89	79	4·21	1	12·08	27	13·28	53	9·99	79	4·04
2	14·98	28	14·94	54	10·62	80	4·02	2	12·93	28	13·18	54	9·76	80	3·86
3	15·82	29	14·83	55	10·35	81	3·80	3	13·65	29	13·10	55	9·52	81	3·66
4	16·27	30	14·72	56	10·06	82	3·61	4	14·04	30	13·02	56	9·28	82	3·47
5	16·59	31	14·62	57	9·77	83	3·41	5	14·33	31	12·94	57	9·03	83	3·29
6	16·74	32	14·51	58	9·48	84	3·21	6	14·46	32	12·86	58	8·77	84	3·10
7	16·79	33	14·39	59	9·20	85	3·01	7	14·52	33	12·77	59	8·53	85	2·91
8	16·79	34	14·26	60	8·94	86	2·83	8	14·53	34	12·68	60	8·30	86	2·74
9	16·74	35	14·13	61	8·71	87	2·69	9	14·50	35	12·57	61	8·11	87	2·60
10	16·67	36	13·99	62	8·49	88	2·60	10	14·45	36	12·47	62	7·91	88	2·52
11	16·58	37	13·84	63	8·26	89	2·50	11	14·38	37	12·35	63	7·71	89	2·42
12	16·49	38	13·70	64	8·02	90	2·34	12	14·32	38	12·24	64	7·50	90	2·27
13	16·41	39	13·54	65	7·77	91	2·32	13	14·26	39	12·12	65	7·28	91	2·25
14	16·32	40	13·39	66	7·50	92	2·41	14	14·19	40	12·00	66	7·05	92	2·34
15	16·23	41	13·25	67	7·23	93	2·52	15	14·13	41	11·89	67	6·80	93	2·44
16	16·14	42	13·10	68	6·94	94	2·57	16	14·07	42	11·78	68	6·55	94	2·49
17	16·07	43	12·96	69	6·64	95	2·60	17	14·01	43	11·67	69	6·28	95	2·52
18	15·99	44	12·81	70	6·34	96	2·56	18	13·96	44	11·55	70	6·00	96	2·49
19	15·90	45	12·65	71	6·02	97	2·43	19	13·90	45	11·43	71	5·70	97	2·37
20	15·82	46	12·48	72	5·71	98	2·28	20	13·84	46	11·30	72	5·42	98	2·23
21	15·73	47	12·30	73	5·44	99	2·05	21	13·77	47	11·15	73	5·17	99	2·00
22	15·63	48	12·11	74	5·19	100	1·62	22	13·70	48	11·00	74	4·94	100	1·60
23	15·53	49	11·89	75	4·99	101	1·19	23	13·62	49	10·82	75	4·76	101	1·18
24	15·42	50	11·66	76	4·79	102	·75	24	13·54	50	10·63	76	4·58	102	·74
25	15·30	51	11·41	77	4·61	103	·32	25	13·46	51	10·42	77	4·41	103	·31

TABLE VII.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

7 per Cent.								8 per Cent.							
Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.
Birth	9·18	26	11·90	52	9·39	78	4·07	Birth	8·18	26	10·71	52	8·68	78	3·91
1	10·61	27	11·83	53	9·21	79	3·88	1	9·44	27	10·65	53	8·52	79	3·74
2	11·34	28	11·76	54	9·01	80	3·71	2	10·09	28	10·59	54	8·36	80	3·58
3	11·98	29	11·69	55	8·81	81	3·52	3	10·65	29	10·54	55	8·18	81	3·40
4	12·32	30	11·64	56	8·60	82	3·35	4	10·96	30	10·50	56	8·00	82	3·24
5	12·57	31	11·58	57	8·38	83	3·17	5	11·18	31	19·45	57	7·80	83	3·07
6	12·70	32	11·52	58	8·15	84	3·00	6	11·30	32	10·41	58	7·61	84	2·90
7	12·76	33	11·45	59	7·94	85	2·82	7	11·35	33	10·35	59	7·42	85	2·73
8	12·77	34	11·37	60	7·74	86	2·65	8	11·37	34	10·30	60	7·25	86	2·57
9	12·75	35	11·30	61	7·57	87	2·52	9	11·36	35	10·24	61	7·10	87	2·44
10	12·72	36	11·21	62	7·40	88	2·44	10	11·33	36	10·17	62	6·95	88	2·37
11	12·67	37	11·12	63	7·23	89	2·34	11	11·30	37	10·10	63	6·80	89	2·28
12	12·62	38	11·03	64	7·04	90	2·20	12	11·26	38	10·03	64	6·63	90	2·13
13	12·57	39	10·94	65	6·85	91	2·18	13	11·22	39	9·95	65	6·46	91	2·12
14	12·52	40	10·85	66	6·64	92	2·27	14	11·18	40	9·88	66	6·27	92	2·20
15	12·47	41	10·76	67	6·42	93	2·37	15	11·14	41	9·84	67	6·08	93	2·30
16	12·43	42	10·67	68	6·19	94	2·42	16	11·11	42	9·74	68	5·87	94	2 35
17	12·39	43	10·59	69	5·95	95	2·45	17	11·08	43	9·67	69	5·64	95	2·38
18	12·35	44	10·49	70	5·69	96	2·42	18	11·05	44	9·60	70	5·41	96	2·36
19	12·31	45	10·40	71	5·42	97	2·31	19	11·02	45	9·52	71	5·16	97	2·25
20	12·26	46	10·29	72	5·16	98	2·18	20	10·99	46	9·44	72	4·92	98	2·[illegible]3
21	12·21	47	10·18	73	4·93	99	1·96	21	10·95	47	9·34	73	4·70	99	1·93
22	12·16	48	10·05	74	4·72	100	1·57	22	10·91	48	9·24	74	4·51	100	1·54
23	12·10	49	9·91	75	4·55	101	1·16	23	10·86	49	9·12	75	4·36	101	1·14
24	12·04	50	9·75	76	4·38	102	·74	24	10·81	50	8·99	76	4·20	102	·73
25	11·97	51	9·57	77	4·23	103	·31	25	10·76	51	8·84	77	4·06	103	·31

TABLE VII.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

9 per Cent.								10 per Cent.							
Age.	Value.	Age.	Value.	Age.	Value	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.
Birth	7·37	26	9·72	52	8·06	78	3·76	Birth	6·72	26	8·89	52	7·52	78	3·62
1	8·50	27	9·67	53	7·93	79	3·60	1	7·73	27	8·85	53	7·40	79	3·47
2	9·08	28	9·62	54	7·78	80	3·45	2	8·25	28	8·81	54	7·27	80	3·33
3	9·58	29	9·58	55	7·63	81	3·28	3	8·71	29	8·77	54	7·14	81	3·17
4	9·86	30	9·55	56	7·47	82	3·13	4	8·95	30	8·75	56	6·99	82	3·03
5	10·06	31	9·51	57	7·29	83	2·97	5	9·14	31	8·72	57	6·84	83	2·88
6	10·17	32	9·48	58	7·12	84	2·81	6	9·24	32	8·69	58	6·69	84	2·73
7	10·22	33	9·44	59	6·95	85	2·64	7	9·29	33	8·66	59	6·54	85	2·57
8	10·24	34	9·39	60	6·80	86	2·50	8	9·31	34	8·62	60	6·40	86	2·42
9	10·24	35	9·34	61	6·67	87	2·37	9	9·30	35	8·58	61	6·29	87	2·30
10	10·21	36	9·29	62	6·54	88	2·30	10	9·29	36	8·53	62	6·17	88	2·23
11	10·18	37	9·23	63	6·40	89	2·21	11	9·26	37	8·49	63	6·05	89	2·15
12	10·15	38	9·17	64	6·26	90	2·07	12	9·24	38	8·44	64	5·92	90	2·02
13	10·12	39	9·11	65	6·10	91	2·05	13	9·21	39	8 39	65	5·78	91	2·10
14	10·09	40	9·05	66	5·94	92	2·14	14	9·19	40	8·34	66	5·64	92	2·08
15	10·06	41	8·99	67	5·76	93	2·23	15	9·16	41	8·29	67	5·47	93	2·17
16	10·03	42	8·94	68	5·57	94	2·28	16	9·14	42	8·25	68	5·30	94	2·22
17	10·01	43	8·88	69	5·37	95	2·32	17	9·12	43	8·21	69	5·12	95	2·26
18	9·99	44	8·83	70	5·15	96	2·30	18	9·10	44	8·16	70	4·92	96	2·24
19	9·96	45	8·76	71	4·92	97	2·20	19	9·09	45	8·11	71	4·70	97	2·15
20	9·94	46	8·70	72	4·70	98	2·08	20	9·06	46	8·06	72	4·50	98	2·04
21	9·91	47	8·62	73	4·50	99	1·89	21	9·04	47	8·00	73	4·31	99	1·86
22	9·88	48	8·54	74	4·32	100	1·52	22	9·02	48	7·93	74	4·14	100	1·49
23	9·84	49	8·44	75	4·18	101	1·13	23	8·99	49	7·84	75	4·01	101	1·11
24	9·80	50	8·32	76	4·03	103	·72	24	8·96	50	7·74	76	3·87	102	·71
25	9·76	51	8·20	77	3·90	103	·31	25	8·92	51	7·63	77	3·75	103	·30

TABLE VIII.

THE PRESENT VALUE OF AN ANNUITY OF ONE POUND ON TWO JOINT LIVES, ACCORDING TO THE CARLISLE TABLE OF MORTALITY.

Example.—An Annuity of £100 to cease on the death of the first of two lives aged 30 and 40 is now worth, at 5 per cent. £1161.

Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.
Years.	Value.	Value.	Value.	Value.	Years.	Value.	Value.	Value.	Value.
5—0	14·38	12·20	10·55	9·27	35—5	16·39	14·39	12·77	11·45
5	19·82	16·80	14·51	12·72	10	16·60	14·59	12·96	11·63
					15	16·29	14·35	12·76	11·46
10—0	14·41	12·28	10·65	9·38	20	16·03	14·14	12·60	11·33
5	19·87	16·91	14·65	12·87	25	15·66	13·85	12·37	11·14
10	19·96	17·05	14·80	13·04	30	15·21	13·49	12·08	10·90
					35	14·72	13·11	11·78	10·67
15—0	13·98	11·97	10·42	9·21					
5	19·29	16·49	14·34	12·63	40—5	15·39	13·63	12·19	10·99
10	19·41	16·64	14·50	12·80	10	15·61	13·83	12·38	11·17
15	18·91	16·27	14·21	12·58	15	15·35	13·62	12·20	11·02
					20	15·13	13·45	12·06	10·90
20—0	13·56	11·68	10·21	9·05	25	14·82	13·20	11·86	10·73
5	18·72	16·10	14·05	12·42	3	14·45	12·90	11·61	10·53
10	18·87	16·26	14·22	12·59	35	14·05	12·58	11·35	10·32
15	18·42	15·92	13·96	12·38	40	13·48	12·13	10·98	10·01
20	17·99	15·61	13·72	12·21					
					45—5	14·33	12·86	11·59	10·52
25—5	18·02	15·59	13·67	12·14	10	14·60	13·07	11·78	10·70
10	18·19	15·77	13·85	12·31	15	14·38	12·88	11·66	10·57
15	17·79	15·46	13·61	12·12	20	14·21	12·74	11·51	10·47
20	17·42	15·18	13·40	11·95	25	13·95	12·53	11·34	10·32
25	16·92	14·80	13·10	11·72	30	13·65	12·28	11·12	10·14
					35	13·33	12·02	10·91	9·97
30—5	17·22	15·00	13·23	11·80	40	12·87	11·64	10·60	9·70
10	17·41	15·22	13·42	11·97	45	12·37	11·24	10·28	9·44
15	17·06	14·92	13·20	11·79					
20	16·75	14·70	13·01	11·65	50—5	13·09	11·83	10·76	9·85
25	16·31	14·34	12·74	11·43	10	13·31	12·04	10·95	10·03
30	15·78	13·93	12·42	11·17	15	13·13	11·88	10·82	9·91

TABLE VIII.—THE PRESENT VALUE OF AN ANNUITY OF ONE POUND ON TWO JOINT LIVES, ETC.—*continued.*

Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.
Years.	Value.	Value.	Value.	Value.	Years.	Value.	Value.	Value.	Value.
50–20	12·99	11·77	10·73	9·83	65–25	8·33	7·78	7·30	6·86
25	12·79	11·60	10·58	9·71	30	8·22	7·69	7·21	6·78
30	12·55	11·39	10·40	9·55	35	8·14	7·61	7·14	6·72
35	12·31	11·20	10·24	9·41	40	8·01	7·19	7·03	6·62
40	11·95	10·90	9·98	9·20	45	7·91	7·41	6·96	6·56
45	11·58	10·59	9·74	8·99	50	7·69	7·22	6·80	6·42
50	10·94	10·06	9·29	8·62	55	7·22	6·80	6·42	6·07
					60	6·59	6·23	5·89	5·59
55—5	11·46	10·47	9·62	8·88	65	6·05	5·74	5·46	5·20
10	11·67	10·66	9·80	9·05					
15	11·53	10·54	9·69	8·95	70—5	6·74	6·35	6·01	5·69
20	11·43	10·46	9·62	8·89	10	6·87	6·48	6·13	5·81
25	11·27	10·33	9·51	8·79	15	6·82	6·43	6·08	5·77
30	11·09	10·16	9·36	8·67	20	6·79	6·41	6·06	5·75
35	10·92	10·02	9·24	8·56	25	6·74	6·36	6·02	5·71
40	10·66	9·80	9·05	8·39	30	6·66	6·29	5·95	5·65
45	10·40	9·58	8·87	8·24	35	6·61	6·24	5·91	5·61
50	9·92	9·18	8·53	7·95	40	6·52	6·16	5·83	5·54
55	9·10	8·46	7·90	7·40	45	6·46	6·11	5·79	5·50
					50	6·34	6·00	5·70	5·42
60—5	9·77	9·02	8·37	7·79	55	6·02	5·71	5·43	5·17
10	9·96	9·20	8·53	7·94	60	5·57	5·29	5·04	4·82
15	9·85	9·10	8·45	7·87	65	5·19	4·96	4·74	4·53
20	9·78	9·04	8·39	7·82	70	4·56	4·37	4·19	4·03
25	9·67	8·94	8·31	7·74					
30	9.53	8·82	8·20	7·64	75—5	5·24	4·99	4·76	4·54
35	9·41	8·72	8·11	7·56	10	5·35	5·09	4·86	4·64
40	9·22	8·55	7·96	7·44	15	5·31	5·06	4·82	4·60
45	9·06	8·42	7·85	7·34	20	5·30	5·04	4·81	4·59
50	8·73	8·13	7·60	7·13	25	5·26	5·01	4·78	4·57
55	8·10	7·57	7·11	6·69	30	5·21	4·96	4·74	4·52
60	7·30	6·85	6·46	6·10	35	5·18	4·93	4·71	4·50
					40	5·11	4·87	4·65	4·45
65—5	8·37	7·81	7·32	6·87	45	5·09	4·85	4·63	4·43
10	8·54	7·97	7·46	7·01	50	5·02	4·79	4·58	4·38
15	8·46	7·90	7·40	6·95	55	4·81	4·60	4·40	4·22
20	8·41	7·86	7·36	6·92	60	4·50	4·30	4·13	3·96

TABLE VIII.—THE PRESENT VALUE OF AN ANNUITY OF ONE POUND ON TWO JOINT LIVES, ETC.—*continued.*

Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.
Years.	Value.	Value.	Value.	Value.	Years.	Value.	Value.	Value.	Value.
75–65	4·26	4·08	3·92	3·77	85–45	3·06	2·95	2·85	2·76
70	3·80	3·66	3·53	3·40	50	3·04	2·94	2·84	2·75
75	3·23	3·12	3·02	2·92	55	2·96	2·86	2·77	2·69
					60	2·81	2·72	2·64	2·56
80 5	4·17	4·00	3·85	3·70	65	2·72	2·64	2·56	2·48
10	4·26	4·09	3·93	3·78	70	2·52	2·45	2·38	2·32
15	4·23	4·06	3·90	3·75	75	2·22	2·16	2·10	2·05
20	4·22	4·05	3·89	3·74	80	1·99	1·94	1·90	1·85
25	4·20	4·03	3·87	3·73	85	1·66	1·62	1·58	1·55
30	4·17	4·00	3·84	3·70					
35	4·15	3·98	3·83	3·68	90–10	2·45	2·37	2·30	2·23
40	4·10	3·94	3·78	3·64	15	2·44	2·36	2·29	2·22
45	4·09	3·92	3·77	3·63	20	2·44	2·36	2·28	2·21
50	4·05	3·89	3·75	3·61	25	2·43	2·35	2·28	2·21
55	3·92	3·77	3·63	3·50	30	2·41	2·33	2·26	2·19
60	3·70	3·56	3·43	3·31	35	2·40	2·32	2·25	2·18
65	3·54	3·42	3·30	3·19	40	2·38	2·30	2·23	2·17
70	3·23	3·12	3·02	2·93	45	2·37	2·30	2·23	2·16
75	2·79	2·70	2·62	2·55	50	2·36	2·29	2·22	2·15
80	2·46	2·39	2·32	2·26	55	2·31	2·24	2·17	2·11
					60	2·20	2·13	2·07	2·01
85—5	3·10	2·99	2·89	2·80	65	2·13	2·07	2·01	1·95
10	3·17	3·06	2·95	2·86	70	1·99	1·93	1·88	1·83
15	3·15	3·04	2·94	2·84	75	1·76	1·71	1·67	1·63
20	3·14	3·03	2·93	2·84	80	1·59	1·55	1·52	1·48
25	3·13	3·02	2·92	2·83	85	1·34	1·31	1·28	1·25
30	3·11	3·00	2·90	2·81	90	1·09	1·07	1·05	1·03
35	3·10	2·99	2·89	2·80	95	1·22	1·19	1·17	1·14
40	3·07	2·96	2·86	2·77	100	0·98	0·96	0·95	0·94

Table IX.

The Present Value of One Pound per Annum held on the Longest of Two Lives, according to the Carlisle Table of Mortality.

Example.—A Lease held on the longest of two lives of the respective ages of 30 and 50 is worth at the present time 15·98 years' purchase, if the purchaser expects 5 per cent. for his money and can invest the Reserved Sum at the same rate.

Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.
Years.	Value.	Value.	Value.	Value.
5—5	27·57	22·38	18·67	15·93
10—5	27·33	22·26	18·61	15·90
10	27·06	22·12	18·54	15·86
15—5	26·99	22·05	18·48	15·82
10	26·68	21·90	18·40	15·77
15	26·26	21·64	18·24	15·67
20—5	26·67	21·86	18·36	15·74
10	26·33	21·68	18·27	15·69
15	25·85	21·39	18·09	15·58
20	25·40	21·11	17·91	15·46
25—5	26·34	21·65	18·22	15·65
10	25·99	21·46	18·12	15·59
15	25·45	21·14	17·92	15·47
20	24·94	20·82	17·72	15·34
25	24·42	20·49	17·51	15·20
30—5	26·03	21·44	18·08	15·55
10	25·66	21·21	17·97	15·50
15	25·08	20·89	17·76	15·35
20	24·50	20·54	17·53	15·21
25	23·91	20·16	17·28	15·04
30	23·33	19·77	17·03	14·87

Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.
Years.	Value.	Value.	Value.	Value.
35—5	25·74	21·24	17·94	15·45
10	25·35	21·03	17·83	15·39
15	24·72	20·65	17·59	15·24
20	24·10	20·26	17·34	15·08
25	23·44	19·84	17·06	14·89
30	22·78	19·40	16·77	14·69
35	22·15	18·97	16·47	14·48
40—5	25·44	21·03	17·79	15·34
10	25·05	20·82	17·68	15·28
15	24·38	20·41	17·42	15·11
20	23·71	19·98	17·15	14·93
25	22·99	19·51	16·84	14·72
30	22·25	19·03	16·50	14·50
35	21·53	18·53	16·16	14·25
40	20·80	18·02	15·80	13·99
45—5	25·17	20·84	17·65	15·23
10	24·77	20·62	17·53	15·17
15	24·46	20·18	17·22	14·98
20	23·35	19·73	16·95	14·79
25	22·58	19·22	16·62	14·56
30	21·77	18·68	16·25	14·31
35	20·97	18·12	15·86	14·03
40	20·14	17·53	15·44	13·73
45	19·35	16·97	15·02	13·41

TABLE IX.—THE PRESENT VALUE OF ONE POUND PER ANNUM HELD ON THE LONGEST OF TWO LIVES, ETC.—*continued.*

Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.
Years.	Value.	Value.	Value.	Value.	Years.	Value.	Value.	Value.	Value.
50—5	24·90	20·63	17·49	15·11	65—5	24·24	20·09	17·04	14·74
10	24·50	20·42	17·38	15·05	10	23·89	19·92	16·97	14·72
15	23·75	19·94	17·07	14·84	15	23·04	19·37	16·60	14·46
20	23·00	19·46	16·75	14·63	20	22·20	18·81	16·22	14·20
25	22·18	18·92	16·38	14·38	25	21·26	18·17	15·77	13·88
30	21·31	18·33	15·98	14·10	30	20·25	17·47	15·28	13·52
35	20·42	17·72	15·55	13·79	35	19·21	16·73	14·75	13·13
40	19·49	17·05	15·06	13·44	40	18·05	15·89	14·12	12·66
45	18·59	16·38	14·57	13·07	45	16·87	15·00	13·45	12·15
50	17·66	15·68	14·03	12·64	50	15·53	13·96	12·63	11·50
					55	14·11	12·81	11·69	10·73
55—5	24·64	20·42	17·32	14·97	60	12·82	11·75	10·81	9·99
10	24·25	20·22	17·22	14·92	65	11·79	10·88	10·07	9·37
15	23·46	19·71	16·88	14·70					
20	22·68	19·20	16·54	14·47	70—5	24·08	19·95	16·92	14·63
25	21·80	18·62	16·15	14·19	10	23·76	19·81	16·87	14·64
30	20·88	17·99	15·71	13·88	15	22·89	19·23	16·48	14·36
35	19·92	17·32	15·23	13·54	20	22·03	18·66	16·09	14·09
40	18·89	16·58	14·69	13·14	25	21·05	18·00	15·62	13·75
45	17·87	15·82	14·12	12·71	30	20·02	17·27	15·10	13·37
50	16·79	14·99	13·48	12·20	35	18·95	16·51	14·55	12·96
55	15·71	14·13	12·79	11·65	40	17·75	15·63	13·89	12·46
					45	16·52	14·70	13·19	11·92
60—5	24·41	20·23	17·16	14·84	50	15·09	13·58	12·30	11·21
10	24·05	20·05	17·08	14·81	55	13·51	12·30	11·25	10·35
15	23·22	19·51	16·72	14·56	60	12·05	11·08	10·23	9·49
20	22·40	18·98	16·36	14·32	65	10·85	10·06	9·36	8·74
25	21·49	18·36	15·94	14·02	70	9·69	9·05	8·48	7·97
30	20·52	17·70	15·47	13·68					
35	19·52	16·99	14·96	13·31	75—5	23·96	19·84	16·82	14·54
40	18·42	16·18	14·37	12·87	10	23·67	19·73	16·80	14·57
45	17·29	15·35	13·74	12·39	15	22·78	19·14	16·40	14·28
50	16·06	14·40	13·00	11·81	20	21·91	18·56	16·00	14·00
55	14·80	13·39	12·18	11·14	25	20·92	17·87	15·52	13·65
60	13·69	12·47	11·42	10·51	30	19·86	17·13	14·98	13·26

Table IX.—The Present Value of One Pound per Annum held on the Longest of Two Lives, Etc.—*continued.*

Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.
Years.	Value.	Value.	Value.	Value.	Years.	Value.	Value.	Value.	Value.
75–35	18·77	16·35	14·41	12·83	85–25	20·77	17·74	15·39	13·54
40	17·54	15·44	13·73	12·32	30	19·68	16·97	14·83	13·12
45	16·29	14·49	13·01	11·76	35	18·57	16·17	14·25	12·68
50	14·79	13·32	12·07	11·01	40	17·31	15·23	13·53	12·14
55	13·11	11·94	10·94	10·07	45	16·04	14·27	12·80	11·57
60	11·51	10·60	9·80	9·11	50	14·49	13·05	11·83	10·79
65	10·17	9·46	8·83	8·27	55	12·68	11·55	10·58	9·75
70	8·83	8·29	7·80	7·35	60	10·91	10·06	9·31	8·66
75	7·79	7·36	6·96	6·60	65	9·43	8·80	8·22	7·71
					70	7·83	7·38	6·96	6·59
80—5	23·88	19·77	16·76	14·49	75	6·52	6·20	5·90	5·62
10	23·61	19·68	16·76	14·49	80	5·60	5·36	5·13	4·92
15	22·71	19·08	16·34	14·23	85	4·80	4·61	4·43	4·27
20	21·84	18·49	15·94	13·95					
25	20·84	17·79	15·44	13·59	90–10	23·56	19·62	16·71	14·48
30	19·75	17·04	14·89	13·18	15	22·64	19·01	16·28	14·18
35	18·65	16·24	14·32	12·75	20	21·76	18·42	15·87	13·89
40	17·41	15·32	13·62	12·22	25	20·74	17·71	15·37	13·52
45	16·14	14·36	12·89	11·66	30	19·64	16·94	14·80	13·09
50	14·61	13·16	11·93	10·88	35	18·53	16·13	14·21	12·66
55	12·85	11·71	10·73	9·88	40	17·26	15·19	13·50	12·10
60	11·16	10·29	9·52	8·85	45	15·99	14·22	12·76	11·53
65	9·74	9·07	8·48	7·95	50	14·44	13·00	11·78	10·74
70	8·26	7·77	7·33	6·93	55	12·60	11·48	10·52	9·68
75	7·09	6·72	6·38	6·07	60	10·79	9·95	9·21	8·56
80	6·27	5·98	5·71	5·46	65	9·29	8·65	8·09	7·59
					70	7·63	7·19	6·79	6·43
85—5	23·82	19·71	16·71	14·44	75	6·25	5·94	5·66	5·40
10	23·57	19·64	16·72	14·50	80	5·27	5·05	4·84	4·64
15	22·66	19·03	16·30	14·19	85	4·39	4·22	4·07	3·92
20	21·78	18·44	15·89	13·91	90	3·91	3·77	3·63	3·51

TABLE X.

THE PRESENT VALUE OF ONE POUND PER ANNUM HELD ON THE LONGEST OF THREE LIVES, ACCORDING TO THE CARLISLE TABLE OF MORTALITY.

Example.—A Lease held on the longest of three lives of the respective ages of 50, 40, and 30, is worth at the present time 16·8 years' purchase at 5 per cent.

Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.
Years.	Value.	Value.	Value.	Value.
10—10—10	28·30	22·89	19·01	16·17
10—15—15	27·84	22·65	18·88	16·10
10—20—10	27·89	22·66	18·89	16·11
20	27·37	22·37	18·71	15·99
10—25—15	27·42	22·40	18·73	16·00
25	26·93	22·10	18·54	15·88
10—30—10	27·56	22·46	18·77	16·03
20	26·98	22·14	18·56	15·90
30	26·50	21·85	18·40	15·79
10—35—15	27·12	22·21	18·62	15·93
25	26·56	21·87	18·40	15·78
35	26·08	21·56	18·22	15·67
10—40—10	27·33	22·32	18·66	15·94
20	26·70	21·95	18·44	15·82
30	26·13	21·59	18·23	15·69
40	25·66	21·27	18·00	15·52
10—45—15	26·92	22·04	18·50	15·85
25	26·26	21·61	18·26	15·70
35	25·70	21·30	18·01	15·53
45	25·25	20·99	17·80	15·38
10—50—10	27·16	22·18	18·56	15·86
20	26·46	21·72	18·32	15·72
30	25·84	21·38	18·08	15·57
40	25·30	21·02	17·81	15·37
50	24·87	20·70	17·58	15·20
10—55—15	26·73	21·92	18·40	15·76
25	26·06	21·51	18·14	15·60
35	25·46	21·12	17·88	15·42
45	24·94	20·75	17·63	15·25
55	24·54	20·45	17·40	17·07

TABLE X.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.
Years.	Value.	Value.	Value.	Value.	Years.	Value.	Value.	Value.	Value.
10—60—10	27·06	22·12	18·51	15·82	15—40—40	25·08	20·93	17·82	15·42
20	26·35	21·70	18·25	15·67	15—50—20	26·02	21·51	18·18	15·64
30	25·70	21·37	17·98	15·50	30	25·30	21·06	17·88	15·45
40	25·12	20·87	17·72	15·30	40	24·68	20·64	17·60	15·25
50	24·62	20·51	17·43	15·08	50	24·18	20·27	17·33	15·05
60	24·27	20·23	17·22	14·93	15—60—20	25·89	21·42	18·10	15·58
10—65—15	26·68	21·88	18·35	15·72	30	25·14	20·94	17·80	15·38
25	25·98	21·45	18·09	15·55	40	24·47	20·48	17·48	15·15
35	25·36	21·04	17·81	15·37	50	23·90	20·06	17·16	14·91
45	24·80	20·64	17·53	15·16	15—70—20	25·82	21·36	18·05	15·54
55	24·33	20·27	17·26	14·95	30	25·06	20·87	17·73	15·32
65	24·03	20·04	17·05	14·79	40	24·37	20·39	17·40	15·09
10—70—10	27·02	22·08	18·51	15·83	50	23·76	19·94	17·06	14·83
20	26·30	21·65	18·25	15·67	60	23·27	19·55	16·75	14·58
30	25·63	21·22	17·96	15·47	70	23·00	19·32	16·56	14·43
40	25·03	20·80	17·66	15·26	20—20—20	26·78	22·04	18·54	15·90
50	24·50	20·41	17·35	15·02	20—30—20	26·25	21·72	18·35	15·78
60	24·08	20·07	17·09	14·82	30	25·62	21·34	18·12	15·63
70	23·85	19·88	16·93	14·68	20—40—20	25·87	21·47	18·18	15·66
15—20—20	27·06	22·20	18·65	15·96	30	25·13	21·00	17·88	15·48
15—30—20	26·60	21·92	18·47	15·86	40	24·50	20·59	17·60	15·28
30	26·05	21·60	18·26	15·73	26—50—20	25·58	21·25	18·01	15·53
15—40—20	26·27	21·71	18·33	15·75	30	24·76	20·73	17·68	15·32
30	25·62	21·30	18·06	15·58	40	24·05	20·25	17·35	15·09

TABLE X.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.	Ages.	3 per Cent.	4 per Cent.	5 per Cent.	6 per Cent.
Years.	Value.	Value.	Value.	Value.	Years.	Value.	Value.	Value.	Value.
20—50—50	23·50	19·84	17·04	14·86	30—70—50	21·34	18·35	16·00	14·11
20—60—20	25·44	21·15	17·93	15·47	60	20·62	17·78	15·54	13·74
30	24·58	20·60	17·57	15·24	70	20·21	17·44	15·25	13·50
40	23·82	20·08	17·21	14·98	40—40—40	22·35	19·18	16·70	14·68
50	23·17	19·60	16·86	14·72	40—50—40	21·48	18·56	16·22	14·32
60	21·71	19·24	16·57	14·50	50	20·41	17·72	15·65	13·90
20—70—20	25·37	21·08	17·89	15·43	40—60—40	21·05	18·22	15·96	14·12
30	24·49	20·52	17·51	15·18	50	19·83	17·33	15·29	13·62
40	23·70	19·98	17·13	14·92	60	19·00	16·67	14·78	13·22
50	23·01	19·46	16·74	14·62	40—70—40	20·83	18·04	15·82	14·00
60	22·47	19·03	16·40	14·35	50	19·55	17·09	15·10	13·46
70	22·16	18·77	16·18	14·17	60	18·56	16·31	14·48	12·96
30—30—30	24·80	20·87	17·83	15·46	70	18·02	15·86	14·10	12·65
30—40—30	24·18	20·42	17·52	15·24	50—50—50	19·06	16·77	14·90	13·53
40	23·34	19·85	17·14	14·98	50—60—50	18·20	16·12	14·40	12·95
30—50—30	23·63	20·04	17·24	15·03	60	16·95	15·14	13·62	12·33
40	22·72	19·39	16·80	14·73	50—70—50	17·76	15·77	14·08	12·69
50	21·97	18·84	16·39	14·42	60	16·30	14·60	13·17	11·95
30—60—30	23·45	19·87	17·11	14·93	70	15·48	13·92	12·60	11·47
40	22·42	19·16	16·62	14·58	60—60—60	15·21	13·76	12·54	11·46
50	21·56	18·53	16·14	14·23	60—70—60	14·16	12·88	11·80	10·83
60	20·95	18·05	15·77	14·93	70	12·84	11·77	10·86	10·04
30—70—30	23·32	19·76	17·02	14·85	70—70—70	10·98	10·20	9·49	8·86
40	22·26	19·03	16·51	14·49					

TABLE XI.

THE PRESENT VALUE OF THE REVERSION TO ONE POUND AT THE END OF THE YEAR AFTER A LIFE DROPS, ACCORDING TO THE CARLISLE TABLE OF MORTALITY.

Example:—The present value of an Assurance of £100 to be paid one year after the death of a person aged 30 is £25·1 at 5 per cent.

3 per Cent.							
Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.
1	·386	26	·375	51	·565	76	·817
2	·345	27	·382	52	·576	77	·824
3	·310	28	·389	53	·587	78	·830
4	·293	29	·395	54	·598	79	·837
5	·281	30	·401	55	·609	80	·844
6	·276	31	·407	56	·621	81	·851
7	·276	32	·414	57	·633	82	·857
8	·278	33	·420	58	·644	83	·864
9	·281	34	·427	59	·655	84	·870
10	·286	35	·434	60	·665	85	·877
11	·291	36	·441	61	·674	86	·883
12	·297	37	·449	62	·683	87	·887
13	·302	38	·456	63	·692	88	·890
14	·308	39	·464	64	·702	89	·893
15	·313	40	·472	65	·711	90	·898
16	·318	41	·479	66	·721	91	·899
17	·323	42	·486	67	·731	92	·896
18	·328	43	·494	68	·742	93	·893
19	·334	44	·501	69	·752	94	·891
20	·339	45	·509	70	·763	95	·891
21	·345	46	·517	71	·775	96	·892
22	·350	47	·525	72	·785	97	·896
23	·356	48	·534	73	·795	98	·901
24	·363	49	·544	74	·803	99	·909
25	·369	50	·554	75	·810	100	·922

TABLE XI.—THE PRESENT VALUE OF THE REVERSION TO ONE POUND, ETC.—*contd.*

3½ per Cent.								4 per Cent.							
Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Ve.
1	·352	26	·328	51	·519	76	·792	1	·325	26	·289	51	·478	76	·769
2	·308	27	·335	52	·531	77	·799	2	·280	27	·295	52	·490	77	·776
3	·272	28	·341	53	·542	78	·806	3	·242	28	·302	53	·502	78	·784
4	·253	29	·348	54	·554	79	·814	4	·222	29	·308	54	·514	79	·793
5	·240	30	·353	55	·566	80	·822	5	·208	30	·313	55	·527	80	·801
6	·235	31	·359	56	·578	81	·830	6	·202	31	·319	56	·540	81	·809
7	·235	32	·365	57	·591	82	·837	7	·200	32	·325	57	·553	82	·817
8	·235	33	·372	58	·603	83	·844	8	·201	33	·331	58	·566	83	·826
9	·238	34	·379	59	·615	84	·852	9	·204	34	·338	59	·578	84	·834
10	·243	35	·386	60	·626	85	·859	10	·208	35	·345	60	·590	85	·842
11	·248	36	·393	61	·636	86	·865	11	·213	36	·352	61	·600	86	·849
12	·253	37	·400	62	·645	87	·871	12	·218	37	·359	62	·610	87	·855
13	·258	38	·408	63	·655	88	·874	13	·223	38	·366	63	·620	88	·858
14	·263	39	·416	64	·665	89	·878	14	·228	39	·374	64	·631	89	·862
15	·268	40	·423	65	·675	90	·883	15	·232	40	·382	65	·642	90	·869
16	·273	41	·431	66	·686	91	·883	16	·237	41	·389	66	·653	91	·869
17	·278	42	·438	67	·697	92	·880	17	·241	42	·396	67	·665	92	·866
18	·283	43	·445	68	·709	93	·876	18	·246	43	·404	68	·678	93	·862
19	·288	44	·453	69	·720	94	·875	19	·251	44	·411	69	·690	94	·860
20	·293	45	·461	70	·732	95	·874	20	·255	45	·419	70	·703	95	·859
21	·298	46	·469	71	·745	96	·876	21	·260	46	·427	71	·717	96	·860
22	·304	47	·478	72	·757	97	·880	22	·266	47	·436	72	·730	97	·866
23	·310	48	·487	73	·767	98	·886	23	·271	48	·445	73	·741	98	·872
24	·316	49	·497	74	·777	99	·894	24	·277	49	·456	74	·752	99	·881
25	·322	50	·508	75	·785	100	·909	25	·283	50	·467	75	·760	100	·898

TABLE XI.—THE PRESENT VALUE OF THE REVERSION TO ONE POUND, ETC.—*contd.*

5 per Cent.								6 per Cent.							
Age.	Value.	Age	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.
1	·286	26	·229	51	·409	76	·724	1	·260	26	·187	51	·353	76	·684
2	·239	27	·235	52	·421	77	·733	2	·212	27	·192	52	·366	77	·694
3	·199	28	·241	53	·434	78	·742	3	·171	28	·197	53	·378	78	·704
4	·178	29	·246	54	·446	79	·752	4	·149	29	·202	54	·391	79	·715
5	·162	30	·251	55	·460	80	·761	5	·133	30	·206	55	·404	80	·725
6	·155	31	·256	56	·473	81	·771	6	·125	31	·211	56	·418	81	·736
7	·153	32	·262	57	·487	82	·781	7	·122	32	·215	57	·432	82	·747
8	·153	33	·267	58	·501	83	·790	8	·121	33	·221	58	·447	83	·757
9	·155	34	·273	59	·514	84	·799	9	·123	34	·226	59	·461	84	·768
10	·159	35	·280	60	·527	85	·809	10	·126	35	·232	60	·473	85	·779
11	·163	36	·286	61	·538	86	·818	11	·129	36	·238	61	·484	86	·788
12	·167	37	·293	62	·548	87	·825	12	·133	37	·244	62	·495	87	·796
13	·171	38	·300	63	·559	88	·829	13	·136	38	·251	63	·507	88	·801
14	·175	39	·308	64	·571	89	·834	14	·140	39	·257	64	·519	89	·807
15	·180	40	·315	65	·583	90	·841	15	·144	40	·264	65	·531	90	·815
16	·184	41	·322	66	·595	91	·842	16	·147	41	·270	66	·544	91	·816
17	·187	42	·329	67	·608	92	·838	17..	·150	42	·277	67	·558	92	·811
18	·191	43	·335	68	·622	93	·833	18	·153	43	·283	68	·573	93	·805
19	·195	44	·343	69	·636	94	·830	19	·157	44	·290	69	·588	94	·802
20	·199	45	·350	70	·651	95	·829	20	·160	45	·297	70	·604	95	·801
21	·203	46	·358	71	·666	96	·831	21	·164	46	·304	71	·621	96	·803
22	·208	47	·367	72	·680	97	·837	22	·168	47	·312	72	·636	97	·809
23	·213	48	·376	73	·694	98	·844	23	·172	48	·321	73	·651	98	·817
24	·218	49	·386	74	·705	99	·855	24	·177	49	·331	74	·664	99	·830
25	·224	50	·397	75	·715	100	·875	25	·182	50	·342	75	·674	100	·853

TABLE XI.—THE PRESENT VALUE OF THE REVERSION TO ONE POUND, ETC.—*contd.*

7 per Cent.								8 per Cent.							
Age.	Value.	Age.	Value.	Age.	Value	Age.	Value	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.
1	·241	26	·156	51	·308	76	·648	1	·221	26	·133	51	·271	76	·615
2	·193	27	·161	52	·320	77	·658	2	·179	27	·137	52	·283	77	·625
3	·151	28	·165	53	·332	78	·669	3	·137	28	·141	53	·295	78	·636
4	·128	29	·170	54	·345	79	·681	4	·114	29	·145	54	·307	79	·649
5	·112	30	·173	55	·358	80	·692	5	·097	30	·148	55	·320	80	·661
6	·104	31	·177	56	·372	81	·704	6	·089	31	·152	56	·334	81	·674
7	·100	32	·181	57	·387	82	·715	7	·085	32	·155	57	·348	82	·686
8	·099	33	·186	58	·401	83	·727	8	·084	33	·159	58	·363	83	·699
9	·100	34	·190	59	·415	84	·738	9	·084	34	·163	59	·376	84	·711
10	·103	35	·196	60	·428	85	·750	10	·086	35	·168	60	·389	85	·724
11	·106	36	·201	61	·439	86	·761	11	·089	36	·173	61	·400	86	·735
12	·109	37	·207	62	·450	87	·770	12	·092	37	·178	62	·411	87	·745
13	·112	38	·213	63	·462	88	·775	13	·095	38	·183	63	·423	88	·751
14	·115	39	·219	64	·474	89	·781	14	·097	39	·189	64	·435	89	·757
15	·119	40	·225	65	·487	90	·791	15	·100	40	·195	65	·448	90	·768
16	·121	41	·231	66	·500	91	·792	16	·103	41	·200	66	·461	91	·769
17	·124	42	·236	67	·515	92	·786	17	·105	42	·205	67	·476	92	·763
18	·127	43	·242	68	·530	93	·780	18	·107	43	·210	68	·491	93	·756
19	·130	44	·248	69	·546	94	·776	19	·109	44	·215	69	·508	94	·752
20	·133	45	·254	70	·562	95	·774	20	·112	45	·221	70	·525	95	·749
21	·136	46	·261	71	·580	96	·775	21	·115	46	·227	71	·544	96	·751
22	·139	47	·269	72	·597	97	·783	22	·118	47	·234	72	·561	97	·759
23	·143	48	·277	73	·612	98	·792	23	·121	48	·241	73	·577	98	·768
24	·147	49	·286	74	·626	99	·806	24	·125	49	·250	74	·592	99	·783
25	·151	50	·297	75	·637	100	·832	25	·129	50	·260	75	·603	100	·812

Table XII.

The Present Value of One Pound per Annum held on a Single Life, according to the English Life Table, No. 3 (Males).

Example.—A Lease for a Life aged 55 is worth at the present time 9·873 years' purchase at 5 per cent. The first payment of the annual profit rent not being received until one year after.

Interest 3 per Cent.

Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.
Birth	18·151	26	19·885	52	12·764	78	4·379
1	21·352	27	19·675	53	12·432	79	4·144
2	22·504	28	19·460	54	12·096	80	3·919
3	23·032	29	19·239	55	11·757	81	3·704
4	23·302	30	19·014	56	11·415	82	3·499
5	23·437	31	18·784	57	11·069	83	3·303
6	23·472	32	18·549	58	10·720	84	3·116
7	23·441	33	18·308	59	10·370	85	2·939
8	23·367	34	18·062	60	10·018	86	2·770
9	23·254	35	17·811	61	9·665	87	2·610
10	23·107	36	17·554	62	9 313	88	2·459
11	22·935	37	17·292	63	8·961	89	2·315
12	22·743	38	17·025	64	8·612	90	2·179
13	22·537	39	16·752	65	8·266	91	2·050
14	22·323	40	16·474	66	7·923	92	1·928
15	22·105	41	16·192	67	7·586	93	1·813
16	21·887	42	15·904	68	7·254	94	1·704
17	21·671	43	15·611	69	6·928	95	1·601
18	21·460	44	15·313	70	6·610	96	1·504
19	21·257	45	15·010	71	6·299	97	1·413
20	21·061	46	14·703	72	5·997	98	1·326
21	20·874	47	14·390	73	5·704	99	1·244
22	20·684	48	14·073	74	5·419	100	1·167
23	20·490	49	13·751	75	5·145	101	1·094
24	20·293	50	13·424	76	4·880	102	1·024
25	20·091	51	13·093	77	4·624	103	0·956

TABLE XII.—THE PRESENT VALUE OF ONE POUND PER ANNUM, ETC.—*continued.*

3½ per Cent.								4 per Cent.							
Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.
Birth	16·441	26	18·395	52	12·151	78	4·286	Birth	14·994	26	17·082	52	11·585	78	4·197
1	19·345	27	18·218	53	11·849	79	4·059	1	17·644	27	16·933	53	11·310	79	3·978
2	20·398	28	18·037	54	11·543	80	3·842	2	18·610	28	16·779	54	11·030	80	3·767
3	20·888	29	17·851	55	11·233	81	3·634	3	19·067	29	16·621	55	10·746	81	3·586
4	21·148	30	17·660	56	10·918	82	3·435	4	19·314	30	16·459	56	10·457	82	3·373
5	21·285	31	17·464	57	10·600	83	3·244	5	19·451	31	16·291	57	10·164	83	3·188
6	21·333	32	17·263	58	10·270	84	3·063	6	19·508	32	16·119	58	9·867	84	3·012
7	21·322	33	17·057	59	9·954	85	2·891	7	19·510	33	15·941	59	9·566	85	2·844
8	21·272	34	16·845	60	9·628	86	2·727	8	19·478	34	15·759	60	9·262	86	2·684
9	21·186	35	16·629	61	9·299	87	2·571	9	19·413	35	15·572	61	8·957	87	2·532
10	21·070	36	16·407	62	8·971	88	2·423	10	19·321	36	15·379	62	8·649	88	2·388
11	20·931	37	16·180	63	8·642	89	2·282	11	19·207	37	15·181	63	8·342	89	2·250
12	20·773	38	15·947	64	8·315	90	2·149	12	19·077	38	14·978	64	8·034	90	2·120
13	20·603	39	15·709	65	7·989	91	2·023	13	18·936	39	14·770	65	7·728	91	1·997
14	20·425	40	15·466	66	7·667	92	1·904	14	18·786	40	14·556	66	7·424	92	1·880
15	20·239	41	15·218	67	7·348	93	1·791	15	18·633	41	14·337	67	7·123	93	1·769
16	20·061	42	14·964	68	7·034	94	1·684	16	18·479	42	14·113	68	6·825	64	1·664
17	19·881	43	14·706	69	6·725	95	1·583	17	18·327	43	13·884	69	6·532	95	1·565
18	19·705	44	14·442	70	6·423	96	1·488	18	18·179	44	13·649	70	6·245	96	1·471
19	19·535	45	14·172	71	6·127	97	1·397	19	18·037	45	13·409	71	5·963	97	1·383
20	19·373	46	13·898	72	5·839	98	1·312	20	17·901	46	13·164	72	5·688	98	1·299
21	19·219	47	13·619	73	5·558	99	1·232	21	17·772	47	12·913	73	5·419	99	1·220
22	19·061	48	13·334	74	5·286	100	1·156	22	17·641	48	12·657	74	5·159	100	1·145
23	18·900	49	13·045	75	5·023	101	1·083	23	17·507	49	12·396	75	4·906	101	1·074
24	18·736	50	12·750	76	4·768	102	1·015	24	17·369	50	12·129	76	4·661	102	1·006
25	18·567	51	12·449	77	4·523	103	0·948	25	17·228	51	11·857	77	4·425	103	0·940

5 per Cent.								6 per Cent.							
Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.
Birth	12·696	26	14·889	52	10·579	78	4·028	Birth	10·972	26	13·143	52	9·712	78	3·870
1	14·939	27	14·781	53	10·348	79	3·823	1	12·905	27	13·063	53	9·518	79	3·679
2	15·764	28	14·669	54	10·113	80	3·626	2	13·619	28	12·979	54	9·318	80	3·494
3	16·161	29	14·553	55	9·873	81	3·437	3	13·967	29	12·893	55	9·114	81	3·316
4	16·384	30	14·433	56	9·627	82	3·255	4	14·167	30	12·802	56	8·904	82	3·144
5	16·515	31	14·309	57	9·377	83	3·081	5	14·289	31	12·709	57	8·688	83	2·980
6	16·579	32	14·180	58	9·121	84	2·914	6	14·355	32	12·611	58	8·467	84	2·822
7	16·599	33	14·047	59	8·862	85	2·755	7	14·383	33	12·510	59	8·242	85	2·671
8	16·590	34	13·910	60	8·598	86	2·603	8	14·387	34	12·404	60	8·012	86	2·526
9	16·553	35	13·768	61	8·332	87	2·458	9	14·368	35	12·295	61	7·778	87	2·388
10	16·494	36	13·621	62	8·063	88	2·320	10	14·329	36	12·181	62	7·541	88	2·257
11	16·417	37	13·469	63	7·792	89	2·189	11	14·274	37	12·062	63	7·301	89	2·131
12	16·325	38	13·312	64	7·520	90	2·065	12	14·208	38	11·940	64	7·060	90	2·011
13	16·224	39	13·151	65	7·248	91	1·946	13	14·132	39	11·813	65	6·817	91	1·898
14	16·115	40	12·984	66	6·976	92	1·834	14	14·051	40	11·681	66	6·573	92	1·790
15	16·004	41	12·813	67	6·706	93	1·727	15	13·967	41	11·545	67	6·331	93	1·687
16	15·891	42	12·636	68	6·439	94	1·626	16	13·882	42	11·403	68	6·089	94	1·590
17	15·780	43	12·454	69	6·174	95	1·530	17	13·798	43	11·257	69	5·849	95	1·497
18	15·673	44	12·267	70	5·913	96	1·440	18	13·717	44	11·106	70	5·611	96	1·409
19	15·570	45	12·074	71	5·657	97	1·354	19	13·641	45	10·950	71	5·377	97	1·326
20	15·473	46	11·877	72	5·405	98	1·273	20	13·569	46	10·789	72	5·146	98	1·248
21	15·382	47	11·673	73	5·159	99	1·196	21	13·504	47	10·623	73	4·920	99	1·173
22	15·289	48	11·465	74	4·919	100	1·123	22	13·436	48	10·451	74	4·699	100	1·102
23	15·194	49	11·250	75	4·686	101	1·054	23	13·366	49	10·273	75	4·483	101	1·035
24	15·095	50	11·030	76	4·459	102	0·988	24	13·294	50	10·090	76	4·273	102	0·971
25	14·994	51	10·804	77	4·240	103	0·925	25	13·220	51	9·901	77	4·068	103	0·908

7 per Cent.								8 per Cent.							
Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value
Birth	9·641	26	11·731	52	8·960	78	3·724	Birth	8·588	26	10·571	52	8·305	78	3·588
1	11·333	27	11·670	53	8·795	79	3·544	1	10·090	27	10·524	53	8·164	79	3·419
2	11·960	28	11·606	54	8·625	80	3·371	2	10·646	28	10·475	54	8·018	80	3·255
3	12·268	29	11·540	55	8·450	81	3·203	3	10·920	29	10·424	55	7·866	81	3·096
4	12·447	30	11·471	56	8·269	82	3·041	4	11·082	30	10·370	56	7·709	82	2·943
5	12·560	31	11·399	57	8·082	83	2·885	5	11·186	31	10·314	57	7·547	83	2·795
6	12·624	32	11·324	58	7·891	84	2·735	6	11·247	32	10·254	58	7·379	84	2·653
7	12·656	33	11·245	59	7·694	85	2·591	7	11·280	33	10·192	59	7·206	85	2·516
8	12·667	34	11·163	60	7·492	86	2·454	8	11·295	34	10·127	60	7·028	86	2·385
9	12·658	35	11·077	61	7·286	87	2·322	9	11·292	35	10·059	61	6·845	87	2·259
10	12·632	36	10·988	62	7·076	88	2·196	10	11·275	36	9·987	62	6·658	88	2·138
11	12·593	37	10·894	63	6·862	89	2·076	11	11·246	37	9·913	63	6·468	89	2·023
12	12·543	38	10·797	64	6·646	90	1·961	12	11·207	38	9·834	64	6·274	90	1·913
13	12·485	39	10·695	65	6·429	91	1·852	13	11·162	39	9·752	65	6·078	91	1·808
14	12·422	40	10·590	66	6·210	92	1·748	14	11·112	40	9·667	66	5·880	92	1·708
15	12·356	41	10·480	67	5·990	93	1·649	15	11·059	41	9·577	67	5·681	93	1·612
16	12·290	42	10·366	68	5·771	94	1·555	16	11·006	42	9·484	68	5·482	94	1·521
17	12·225	43	10·247	69	5·552	95	1·465	17	10·954	43	9·386	69	5·282	95	1·435
18	12·162	44	10·124	70	5·336	96	1·380	18	10·904	44	9·284	70	5·083	96	1·352
19	12·104	45	9·996	71	5·121	97	1·300	19	10·857	45	9·178	71	4·886	97	1·274
20	12·049	46	9·863	72	4·909	98	1·223	20	10·815	46	9·068	72	4·691	98	1·199
21	12·001	47	9·725	73	4·701	99	1·150	21	10·778	47	8·953	73	4·498	99	1·128
22	11·950	48	9·582	74	4·496	100	1·081	22	10·739	48	8·833	74	4·308	100	1·061
23	11·898	49	9·434	75	4·296	101	1·015	23	10·700	49	8·708	75	4·122	101	0·999
24	11·844	50	9·280	76	4·100	102	0·952	24	10·659	50	8·577	76	3·939	102	0·934
25	11·788	51	9·120	77	3·909	103	0·891	25	10·616	51	8·441	77	3·761	103	0·866

TABLE XIII.

THE NET ANNUAL PREMIUM WHICH WILL INSURE ONE POUND OVER THE WHOLE TERM OF LIFE, ACCORDING TO THE ENGLISH LIFE TABLE, No. 3 (MALES).

Example.—The annual premium to be paid for an insurance of £100 on a life aged 30 is £2·08 or £2 1*s.* 7*d.*, when no charge is made for expenses of management, &c.

3 per Cent.							
Age.	Value.	Age.	Value.	Age.	Value.	Age.	Value.
1	·0156	26	·0188	51	·0418	76	·1410
2	·0134	27	·0192	52	·0435	77	·1487
3	·0125	28	·0198	53	·0453	78	·1568
4	·0120	29	·0203	54	·0472	79	·1653
5	·0118	30	·0208	55	·0493	80	·1742
6	·0117	31	·0214	56	·0514	81	·1835
7	·0118	32	·0220	57	·0537	82	·1932
8	·0119	33	·0227	58	·0562	83	·2033
9	·0121	34	·0233	59	·0588	84	·2138
10	·0124	35	·0240	60	·0616	85	·2248
11	·0127	36	·0248	61	·0646	86	·2361
12	·0130	37	·0255	62	·0678	87	·2479
13	·0134	38	·0264	63	·0713	88	·2600
14	·0137	39	·0272	64	·0749	89	·2726
15	·0142	40	·0281	65	·0788	90	·2854
16	·0146	41	·0290	66	·0829	91	·2987
17	·0150	42	·0300	67	·0873	92	·3124
18	·0154	43	·0311	68	·0920	93	·3264
19	·0158	44	·0322	69	·0970	94	·3406
20	·0162	45	·0333	70	·1023	95	·3554
21	·0166	46	·0346	71	·1079	96	·3698
22	·0170	47	·0359	72	·1138	97	·3850
23	·0174	48	·0372	73	·1200	98	·3998
24	·0178	49	·0387	74	·1267	99	·4155
25	·0183	50	·0402	75	·1336	100	·4295

NOTE.—The rates in the above table when increased by one-tenth, to cover the expenses of management, &c., will correspond with the premiums charged by most Life Assurance Companies.

Table XIV.—Annual Payment to Liquidate £100 Principal and Interest in a given Number of Years. (*See* p. 416.)

Years. required.	Rate of Interest per Annum.						
	2½ per Cent.	2¾ per Cent.	3 per Cent.	3½ per Cent.	4 per Cent.	4½ per Cent.	5 per Cent.
5	21·5259	21·6799	21·8355	22·1483	22·4628	22·7792	23·0975
10	11·4261	11·5740	11·7231	12·0242	12·3289	12·6379	12·9505
15	8·0766	8·2259	8·3767	8·6825	8·9941	9·3114	9·6342
20	6·4163	6·5672	6·7212	7·0361	7·3605	7·6876	8·0243
25	5·4276	5·5840	5·7428	6·0674	6·4012	6·7439	7·0952
30	4·7778	4·9385	5·1019	5·4371	5·7830	6·1392	6·5051
35	4·3205	4·4857	4·6539	4·9998	5·3577	5·7270	6·1072
40	3·9836	4·1532	4·3126	4·6827	5·0524	5·4313	5·8278
45	3·7267	3·9007	4·0784	4·4454	4·8263	5·2262	5·6262
50	3·5258	3·7041	3·8866	4·2634	4·6550	5·0602	5·4777
60	3·2354	3·4220	3·6[illegible]33	4·0089	4·4202	4·8454	5·2828
70	3·0394	3·2312	3·4352	3·8461	4·2745	4·7165	5·1699
80	2·9026	3·1043	3·3112	3·7385	4·1814	4·6371	5·1030
90	2·8038	3·0121	3·2256	3·6658	4·1208	4·5873	5·0627
100	2·7312	2·9454	3·1647	3·6151	4·0808	4·5559	5·0383

TABLE XV.

THE DECIMAL PARTS OF ONE POUND.

s.	d.	Decim.	s.	d.	Decim.	s.	d.	Decim.	s.	d.	Decim.
0	0½	·0021	3	0	·1500	6	0	·3000	9	0	·4500
	1	·0041		1	·1541		1	·3041		1	·4541
	2	·0083		2	·1583		2	·3083		2	·4583
	3	·0125		3	·1625		3	·3125		3	·4625
	4	·0166		4	·1666		4	·3166		4	·4666
	5	·0208		5	·1708		5	·3208		5	·4708
	6	·0250		6	·1750		6	·3250		6	·4750
	7	·0291		7	·1791		7	·3291		7	·4791
	8	·0333		8	·1833		8	·3333		8	·4833
	9	·0375		9	·1875		9	·3375		9	·4875
	10	·0416		10	·1916		10	·3416		10	·4916
	11	·0458		11	·1958		11	·3458		11	·4958
1	0	·0500	4	0	·2000	7	0	·3500	10	0	·5000
	1	·0541		1	·2041		1	·3541		1	·5041
	2	·0583		2	·2083		2	·3583		2	·5083
	3	·0625		3	·2125		3	·3625		3	·5125
	4	·0666		4	·2166		4	·3666		4	·5166
	5	·0708		5	·2208		5	·3708		5	·5208
	6	·0750		6	·2250		6	·3750		6	·5250
	7	·0791		7	·2291		7	·3791		7	·5291
	8	·0833		8	·2333		8	·3833		8	·5333
	9	·0875		9	·2375		9	·3875		9	·5375
	10	·0916		10	·2416		10	·3916		10	·5416
	11	·0958		11	·2458		11	·3958		11	·5458
2	0	·1000	5	0	·2500	8	0	·4000	11	0	·5500
	1	·1041		1	·2541		1	·4041		1	·5541
	2	·1083		2	·2583		2	·4083		2	·5583
	3	·1125		3	·2625		3	·4125		3	·5625
	4	·1166		4	·2666		4	·4166		4	·5666
	5	·1208		5	·2708		5	·4208		5	·5708
	6	·1250		6	·2750		6	·4250		6	·5750
	7	·1291		7	·2791		7	·4291		7	·5791
	8	·1333		8	·2833		8	·4333		8	·5833
	9	·1375		9	·2875		9	·4375		9	·5875
	10	·1416		10	·2916		10	·4416		10	·5916
	11	·1458		11	·2958		11	·4458		11	·5958

TABLE XV.

THE DECIMAL PARTS OF ONE POUND.—*continued.*

s.	d.	Decim.	s.	d.	Decim.	s.	d.	Decim.	s.	d.	Decim.
12	0	·6000	14	0	·7000	16	0	·8000	18	0	·9000
	1	·6041		1	·7041		1	·8041		1	·9041
	2	·6083		2	·7083		2	·8063		2	·9083
	3	·6125		3	·7125		3	·8125		3	·9125
	4	·6166		4	·7166		4	·8166		4	·9166
	5	·6208		5	·7208		5	·8208		5	·9208
	6	·6250		6	·7250		6	·8250		6	·9250
	7	·6291		7	·7291		7	·8291		7	·9291
	8	·6333		8	·7333		8	·8333		8	·9333
	9	·6375		9	·7375		9	·8375		9	·9375
	10	·6416		10	·7416		10	·8416		10	·9416
	11	·6458		11	·7458		11	·8458		11	·9458
13	0	·6500	15	0	·7500	17	0	·8500	19	0	·9500
	1	·6541		1	·7541		1	·8541		1	·9541
	2	·6583		2	·7583		2	·8583		2	·9583
	3	·6625		3	·7625		3	·8625		3	·9625
	4	·6666		4	·7666		4	·8666		4	·9666
	5	·6708		5	·7708		5	·8708		5	·9708
	6	·6750		6	·7750		6	·8750		6	·9750
	7	·6791		7	·7791		7	·8791		7	·9791
	8	·6833		8	·7833		8	·8833		8	·9833
	9	·6875		9	·7875		9	·8875		9	·9875
	10	·6916		10	·7916		10	·8916		10	·9916
	11	·6958		11	·7958		11	·8958		11	·9958

DILAPIDATIONS.

Dilapidation is, in general terms, the impairment or waste which property has suffered while in the possession of a tenant or other person responsible for the repairs.

The responsibilities to which a tenant may be subject are of two kinds—one for maintaining the property so that it will be restored to the owner at the end of the term in the same state of repair as it was at the commencement, allowance being made for the unavoidable deterioration due to time; and the other for the avoidance of waste due to carelessness, negligence, or wilful damage.

NOTE.—Owing to the imperfect methods of building adopted in the present day, by which the life of a structure is considerably shortened, a tenant should not be held responsible for more than ordinary repairs. Walls may bulge or fall owing to the use of garden mould instead of mortar in their construction; chimney breasts may crack from the same cause. Floor boards may be so thin or so unseasoned as to warp or show open joints, or the floor joists may be so weak as to cause the floor to vibrate with every step on it. Door panels may shrink from their styles. Roof timbers may be so shallow as to sag from the heat of the sun or from the load which they were intended to sustain. Ceilings may be formed of a large admixture of garden mould instead of lime and hair, or the laths may be so slight as to be unable to sustain the plaster. Water pipes may be so placed that they burst during frost. Cocks and taps are often made of such soft metal that they soon wear out. These, along with a variety of other defects inherent to the structure, owing to the manner of building, make it unjust to hold a tenant responsible for them as of old.

The following are some of the defects in buildings that usually come under the head of dilapidations when the tenant is bound to keep the premises in repair:

Bricklayers' Work—

Brickwork *defective* in walls, chimney shafts, parapets, &c.

Walls *out of the perpendicular*, cracked, split, or bulged, so as to be unsafe or incapable of being effectually repaired, if caused by the neglect of the tenant.

Mortar joints, or pointing to door and window frames, &c., *decayed*.

Doorway broken through a party wall.

Tiles *loose* or *defective*.
Chimney-pots *loose* or *broken*.
Cement or mortar fillets *defective*.
Pavings (brick or tile) *broken* or *defective*.
Drains or cesspools *stopped* or out of *repair*.
Accumulations of soil and rubbish.

Masons' Work—

Stonework *loose, damaged*, or *defective*, such as copings, or curbs to areas and railings.
Hearths or back hearths *broken* or *cracked*.
Mortar joints *open* or *decayed*.
Cramps *defective*
Water channels *defective*.
Sinks ,,
Shelves ,,
Pavings ,, or *out of level*.
And other parts of the building, both external and internal, when *loose, damaged*, or *defective*, also chimney-pieces, slabs, and inner hearths, when *broken* or *out of level*.

NOTE.—Broken or damaged portions of steps, landings, cornices, lintels, sills, string-courses, plinths, and other stone dressings, may be repaired by filling in pieces where it can be done in a sound and efficient manner,

Slaters' and Slate Masons' Work—

Slates or ridges *loose, broken*, or *defective*.
Shelves, slabs, or pavings *broken* or *loose*.

Carpenters' and Joiners' Work—

Roof timbers *loose, broken*, or *defective*.
Floor joists, rafters, &c., *out of level* (if caused by the neglect of the tenant) or *decayed from dry rot*.
Wood fences, gates and posts, &c., *loose, broken, decayed*, or *defective*.

NOTE.—When the bottoms only of posts are decayed, the tenant may be allowed to put spurs thereto instead of new posts.

Cistern covers, weather boarding, fascias, &c., *broken* or *defective*.
Doors and frames, skirtings, dressers, cupboards, &c., *broken* or *defective*.
Floors, broken, rotten, or loose, or *out of level*, when occasioned by neglect.
Hinges and fastenings to doors or shutters, when *loose, broken*, or *defective*.

Sashes and frames injured or decayed, sash lines *broken*, or fastenings *defective.*

Handrails, balusters, treads and risers of stairs, or other joiners' work, in any way *injured* or *defective.*

Smiths' and Ironmongers' Work—

Ironwork of every description throughout the premises, when *loose, broken, damaged* or *decayed* owing to neglect.

Iron gates, &c., badly hung, or the fastenings *imperfect.*

Plasterers' Work—

Plastering, *loose, damaged,* or *defective,* owing to neglect.
Mouldings or enrichments, when *broken* or *defaced.*
Whitening and colouring of walls, when *soiled* or *damaged.*
Nail holes in plastering.

Plumbers' Work—

Leadwork in flats, gutters, hips, ridges, valleys, flashings, cistern heads, and pipes, the portions *damaged, loose,* or *defective.*

Pumps, water-closets, soil pipes, &c., when *damaged* or out of *repair.*

Painters', Glaziers', and Paperhangers' Work—

External painting, when *neglected,* to wood or iron, so as to affect its preservation.

Paint on stonework, or stucco, &c., when *defaced.*

NOTE.—Inside painting, except when damaged or defective, is not supposed to be renewed, unless so expressed in the lease or agreement.

Broken glass and defective putty are dilapidations, also defective leadwork to lights, &c.

NOTE.—Glass with only one crack, except when in superior rooms, is not usually required to be renewed.

Wall paper, *loose, torn,* or *soiled,* as by hanging pictures, resting furniture against the wall or otherwise.

NOTES.

According to English law TENANTS AT WILL are not liable for dilapidations.

TENANTS FROM YEAR TO YEAR are liable only for dilapidations resulting from avoidable accident, carelessness, negligence, wilful or other

damage that may arise through neglect, as, for example, in not giving notice to the landlord of defects which he should repair.

AGRICULTURAL DILAPIDATIONS.—The extent of the tenant's liability in this case is usually fixed by covenant or local custom, but as a general rule a tenant is liable for waste or damage that injuriously affects the value of the estate. Ornamental repairs are seldom required in an agricultural tenancy, and are never implied unless specially covenanted for.

ECCLESIASTICAL DILAPIDATIONS.—An Incumbent of the English Church is bound to maintain the buildings attached to his benefice in a good and substantial state of repair, even though it may become necessary entirely to rebuild. It is not sufficient that he preserves them from actual decay, but he must renew and restore from time to time such portions as from age or accident are so far dilapidated as to be liable in a short period to become useless, although they be not as yet actually so. At the same time he is not under any obligation to modernise or improve the tenements, nor to bear the expense of any ornamental or decorative works, such as whitewashing, papering, or painting, unless to preserve exposed timbers from decay (*Wise* v. *Metcalfe*). The Incumbent is also bound to keep the chancel of his church in repair.—See *Cripps*' '*Law relating to the Church and Clergy.*'

FIXTURES.

Intimately connect d with the subject of dilapidations is that of fixtures, as the removal of those belonging to the landlord is a "waste" which should be assessed along with the dilapidations.

A fixture may be described as something attached to the land directly or indirectly, and which becomes a part of the freehold. This in ordinary cases cannot be removed by any one except the freeholder. A tenant, however, may remove what he has placed for the convenience of his *trade*, such as engines, counters, brewing vessels, &c., but erections for the purpose of farming and agriculture, if once attached to the freehold, do not come under this exception, and cannot be taken down again.

Doors, windows, floors, wainscot, and other things which are usually considered as *permanently* fixed, cannot be moved; but pier or chimney glasses, bookcases, cupboards fixed with screws or holdfasts, wainscot and chimney-pieces, if *temporarily* fixed, may be removed provided the removal does not cause serious *damage* to the premises.

Damage, however slight, caused by the removal of fixtures becomes a dilapidation, which must be made good at the expense of the tenant.

All fixtures put up by the tenant must be removed *during* his term; or his right to them lapses, and they become the landlord's property.

Fixtures Removable by the Tenant if annexed by him and will not cause damage to the freehold.

Agricultural machines.
Apparatus for heating houses.
Aviaries.
Baize doors.
Barns and other buildings set on blocks.
Baths.
Bells, &c.
Bins, except of bricks.
Blinds.
Bookcases.
Bottle racks.
Brackets.
Cabinets.
Chimney-pieces, ornamental and temporarily fixed.
Chimney-glasses.
Cisterns, temporarily fixed.
Clock cases.
Clothes posts.
Coffee mills.
Coppers.
Cornices, ornamental.
Cupboards, temporarily fixed.
Doors or gates, supplementary.
Eyes for stair-rods.
Finger plates.
Furnaces.
Gas fittings, except pipes let into the wall.
Gas stoves.
Grates, slightly attached.
Hangings, as tapestry, &c.
Hat rails and pins.
Iron backs to chimneys.
Iron ovens.
Iron safes.
Jacks.
Lamps.
Looking-glasses.
Mouldings, ornamental.
Ornamental fixtures.
Ovens.
Overmantels.
Paling.
Picture rods.
Pier-glasses.
Presses.
Pumps, slightly attached.
Rails.
Ranges, slightly attached.
Sheds, ditto.
Shelves and their brackets.
Shutters (loose) to doors and windows.
Sinks.
Stoves, slightly attached.
Sun-blinds and their casings.
Tapestry, except when fixed to the wall by mouldings, &c., which could not be removed without injury to the freehold.
Turret clocks.
Water-closet apparatus, except where fixed to the freehold.

Trade Fixtures held to be Removable.

Agricultural machines.
Bar fittings to public-houses.
Brewing vessels and pipes.
Cider mills.
Cisterns.
Closets.
Colliery machines.
Coppers,
Counters.
Cranes.
Desks.
Drawers.
Engines, and houses built to contain them.
Fire-engines.
Flowers for sale in a nursery.
Furnaces.
Gas pipes, temporary.
Glass fronts to shops.
Iron safes.
Partitions, temporary.
Presses.
Pumps.
Reservoirs, or tanks.
Salt pans.
Shelves.
Shrubs and trees planted for sale.
Soap works.
Steam-engines.
Stills.
Sun-blinds.
Vats.

Articles held not to be Removable.

Box borders.
Carpenter's shop, smithy, &c.
Chimney-pieces, not ornamental.
Coach or cart houses.
Conservatories, when connected with the adjoining house.
Doors.
Dressers.
Flowers.
Fruit and other trees, except by nurserymen.
Glass windows.
Hearths.
Hedges.
Keys.
Locks.
Mill stones.
Partitions, except trade.
Pigeon-house.
Racks in stables.
Strawberry-beds.
Verandah, though attached to the ground by posts or piers.
Waggon sheds.

SCALE OF PROFESSIONAL CHARGES FOR ARCHITECTS, SURVEYORS, &c.

Architects' rates—

1. Preliminary sketches and designs complete, including survey of site, &c.	$1\frac{1}{4}$ per cent.
2. General drawings, plans, elevations, and sections, specification, and approximate estimate	$1\frac{1}{4}$,,
3. Working and detail drawings	$1\frac{1}{4}$,,
4. Personal supervision and superintendence, exclusive of clerk of works	$1\frac{1}{4}$,,
Total charge per cent	5

NOTE.—The above charge of 5 per cent. is to be estimated on the value of the work executed, including such materials and labour as may be supplied by the owner; omitted work is to be paid for under items 1, 2, and 3, according to the stage of the proceedings at which the alteration was determined upon.

Procuring and examining tenders for the work	$\frac{1}{4}$ per cent. in addition to the foregoing.
Arranging with artists, tradesmen, and others for sculpture, stained glass, and works of a similar class, for which the architect does not furnish the design, but to which he gives a general supervision ..	$2\frac{1}{2}$ per cent. on the value.
Alterations in the design, extra labour in attending committee meetings, arranging disputes with adjoining owners, &c. ..	at per day.
Travelling and incidental expenses	extra.
Measuring up works and certifying the builder's accounts for extras and omissions	as per surveyors' rates.

An architect is bound under the 5 per cent. charge to provide one set of drawings and one set of tracings, with duplicate specification; it being understood that the architect is paid for

the use only of the drawings and specification, and that they remain his property at the completion of the work.

NOTE.—A copy of the drawings and specifications should, however, be supplied to the building owner if demanded.

Payment on account, at the rate of 5 per cent, to be made on the instalments paid to the builder, or otherwise to half the commission on the signing of the contract, and the remainder by instalments as above.

Surveyors' rates—

The charge for measuring works in small new buildings, and in repairs, including a bill of the particulars, is	2½ per cent.
For large new works of plain character, the usual charge is..	1½ „

When the works are of elaborate construction or the value is small compared with the number of dimensions required, the charge will vary from 1½ per cent. upwards, according to the additional trouble entailed in measuring.

For works of very small value the charge is by the day.

Estimating quantities from plans and specifications, and preparing the "bills of quantities" —for very small or difficult works the charge is	2½ per cent.
Ditto, for ordinary works of 10,000*l.* value or under .. .., ...	1½ „
Ditto above 10,000*l.*, the first 10,000*l.* being charged under the last item	1 „

Lithographing and travelling expenses are charged extra.

In important works where the quantities are taken out conjointly by two different surveyors, half of the above rates are due to each surveyor. In large works of very plain character, especially when many simple repetitions occur, lower rates than the foregoing are sometimes considered sufficient.

Valuations of Property—

SCALE KNOWN AS "RYDE'S."

On the first 100*l.*	5 guineas per cent.
„ second to fifth ..	2 „
„ sixth to tenth ..	1 „
Above 1000*l.*	½ „ The first thousand being charged at 18 guineas.

Minimum rate charged by architects and surveyors when paid by the day = 3 guineas.

Scale adopted by the Royal Institute of British Architects.

On the first 1000*l*.	1 per cent.	Exclusive of travelling expenses.
On remainder, up to 10,000*l*.	½ ,,	

For Dilapidations: 5 per cent. on the estimate, but in no case less than 2 guineas.

Land Surveyors' Charges.

	£	s.	d.
Surveys of estates when the gross contents only are required, with a map showing the boundary. For the first 100 acres	7	10	0
Ditto, ditto. For each additional acre	0	0	9
Ditto, ditto, when the contents of each farm are required, and the boundaries are shown on the map. For the first 100 acres	10	0	0
Ditto, ditto. For each additional acre	0	1	0
Ditto, ditto, when the contents of each field are required, and the fields, buildings, &c., are shown on the map, For the first 100 acres	15	0	0
Ditto, ditto. For each additional acre	0	1	6

Surveys of buildings and building plots, by special arrangement.

Note.—Railway fare to be charged extra, but all other expenses are included in the foregoing rates.

Auctioneers' Charges.

The sale of estates, houses, &c., for the first 100*l*.		5 per cent.
Ditto	above 100*l*. and under 1,000*l*.	2½ ,,
Ditto	,, 1,000*l*. ,, 10,000*l*.	1½ ,,
Ditto	,, 10,000*l*.	1 ,,

Advertisements, Travelling Expenses, &c., extra.

Land and House Agents' Charges.

Letting estates, farms, houses, &c. On the first year's rental	5 per cent.
Ditto, if on lease, an extra charge on the second year's rental of	2½ ,,

Ditto, building land, the charge is one year's standing ground-rent.

Advertisements, Travelling Expenses, &c., extra.

Collecting the rents of estates and houses, 2½ to 5 per cent. according to the class of property.

APPENDIX.

WEIGHTS AND MEASURES.

Long Measure.

inches							
12 =	1 foot.						
36 =	3 =	1 yard.					
72 =	6 =	2 =	1 fathom.				
198 =	16·5 =	5 5 =	2·75 =	1 perch.			
7920 =	660 =	220 =	110 =	40 =	1 furlong.		
63360 =	5280 =	1760 =	880 =	320 =	8 =	1 mile.	

Land Measure.

inches			
7·92 =	1 link.		
792 =	100 =	1 chain.	
63360 =	8000 =	80 =	1 mile.

Nautical Measure.

knots
1 = 6075·6 feet (or 6080 feet, Admiralty).
3 = 1 league.
60 = 1 degree = 69·04 English miles.
A cable's length = 607·56 feet = $\frac{1}{10}$th of a sea mile.

Square Measure.

inches					
144 =	1 foot.				
1296 =	9 =	1 yard.			
39204 =	272·25 =	30·25 =	1 perch.		
1568160 =	10890 =	1210 =	40 =	1 rood.	
6272640 =	43560 =	4840 =	160 =	4 =	1 acre.

Land Measure (Square).

links			
625 =	1 perch.		
10000 =	1 chain.		
25000 =	2·5 =	1 rood.	
100000 =	10 =	4 =	1 acre.

SCOTCH AND IRISH MEASURE.

English mile	= 1760	yards ..	..	= 1·00000
Scotch ,,	= 1984	,, ..	..	= 1·12159
Irish ,,	= 2240	,, ..	..	= 1·27273
English acre	= 4810	square yards		= 1·00000
Scotch ,,	= 6150·4	,,		= 1·27074
Irish ,,	= 7840	,,		= 1·61983

SOLID MEASURE.

cubic inches
1728 = 1 cubic foot.
46656 = 27 = 1 cubic yard.

DRY MEASURE.

gallons					
2 =	1 peck.				
8 =	4 =	1 bushel = 1·2837 cubic feet.			
64 =	32 =	8 =	1 quarter.		
320 =	160 =	40 =	5 =	1 load or wey.	
640 =	320 =	80 =	10 =	2 =	1 last.

LIQUID MEASURE.

cubic inches							
34·66 =	1 pint.						
69·318 =	2 =	1 quart.					
277·274 =	8 =	4 =	1 gallon.				
11645·508 =	336 =	168 =	42 =	1 tierce.			
17467·262 =	504 =	252 =	63 =	1½ =	1 hogshead.		
23291·016 =	672 =	336 =	84 =	2 =	1⅓ =	1 puncheon.	
34936·524 =	1008 =	504 =	126 =	3 =	2 =	1½ =	1 pipe.
69873·048 =	2016 =	1008 =	252 =	6 =	4 =	3 =	2 = 1 tun.

NOTE.—The imperial gallon contains 10 lbs. distilled water at 62° Fahr., and a cubic foot contains 6·2321 imperial gallons.

277·123 cubic inches is the actual contents of a gallon, but by Act of Parliament it is fixed at 277·274 cubic inches (or 277·463 cubic inches, 1890).

AVOIRDUPOIS WEIGHT.

drachms					
16 =	1 oz. = 437·5 grains troy.				
256 =	16 =	1 lb. = 1·2153 lbs. troy.			
7168 =	448 =	28 =	1 quarter.		
28672 =	1792 =	112 =	4 =	1 cwt.	
573440 =	35840 =	2240 =	80 =	20 =	1 ton.

Troy Weight.

grains
24 = 1 dwt.
480 = 20 = 1 oz.
5760 = 240 = 12 = 1 lb. = 22·816 cubic inches of distilled water at 62° Fahr.

Apothecaries' Weight (New).

grains
437·5 = 1 oz.
7000 = 16 = 1 lb.

Ditto Measure.

60 min. .. .. = 1 fluid drachm.
8 fluid drachms = 1 ,, oz.
20 ,, oz. .. = 1 pint.
8 pints .. .. = 1 gallon.

Cloth.

$2\frac{1}{4}$ inches = 1 nail = $\frac{1}{16}$ yard.
9 ,, = 4 ,, = $\frac{1}{4}$,,
36 ,, = 16 ,, = 1 ,,

Coal.

112 lbs. .. .. = 1 cwt.
2 cwt. .. .. = 1 sack.
10 sacks.. .. .. .. = 1 ton.

Glass.

5 lbs. .. .. = 1 stone.
24 stone .. .. = 1 seam.

12 articles .. .. .. = 1 dozen.
13 ,, ... = 1 long dozen.
20 ,, ... = 1 score.
5 score .. .. .. = 1 hundred.
6 ,, ... = 1 long hundred.
12 dozen .. .. .. = 1 gross.

Time.

seconds
60 = 1 minute.
3600 = 60 = 1 hour.
86400 = 1440 = 24 = 1 day.
604800 = 10080 = 168 = 7 = 1 week.
2419200 = 40320 = 672 = 28 = 4 = 1 month.
12 months = 1 year.

MISCELLANEOUS ARTICLES.

The old wine gallon	= 231 cubic inches.
,, ale gallon	= 281 ,,
A stone	= 14 lbs.
20 articles	= 1 score.
12 dozen	= 1 gross.
A cord of wood	= 128 cubic feet.
A faggot of steel	= 120 lbs.
A cask of black-lead	= $11\frac{1}{2}$ cwt.
Pig of ballast	= 56 lbs.
A fodder of lead (London)	= 2184 lbs.
Truss of straw	= 36 ,,
,, hay	= 56 ,,
A load of hay or straw	= 36 trusses.
A ton of straw	= 16 cubic yards.
A firkin	= 1·444 cubic foot.
A corn bushel	= 1·284 ,,
A barrel of tar	= 25 gallons.
A ton of Portland cement	= 6 casks.
,, ,, ,, ...	= 10 sacks.
A bolt of canvas	= 39 yards.
A knot of sashline	= 12 yards.
A piece of wall paper	= 12 ,,
A bag of lime	= 2150·4 cubic inches.
,, plaster of Paris	= 14 lbs.
8 bags of ditto	= 1 bushel.
1 hundred of lime	= 100 pecks.
	= 25 Winchester bushl. of 1·244 cub. ft.

ADMIRALTY CASES.

	Size.	Contents, gallons.
Leager	59" × 38"	.. 164
Butt..	53 × 38	.. 110
Puncheon	$41\frac{1}{2}$ × 30	.. 72
Hogshead	37 × 28	.. 54
Barrel	$31\frac{1}{2}$ × $21\frac{1}{2}$	.. 36
Half-hogshead	28 × $22\frac{1}{2}$	.. 27
Kilderkin	25 × $19\frac{3}{4}$	.. 18
Firkin	22 × 17	.. 12

SUNDRY CASKS.

	Extreme Size.	Contents, gallons.
	" "	
Port pipe	58 × 34	113
,, hog-head	37 × 30	56½
Sherry butt	50 × 35	108
,, hogshead	38 × 28	54½
Marsala pipe	65 × 32	91
,, hogshead	41 × 25	45½
Brandy pipe	52 × 34	114
,, hogshead	40 × 28	57½
Rum puncheon	42 × 36	91

PAPER.

24 sheets	= 1 quire.
20 ,,	= 1 ,, of outsides.
25 ,,	= 1 ,, printer's.
20 quires	= 1 ream.
21½ ,,	= 1 printer's ream.
2 reams	= 1 bundle.
10 ,,	= 1 bale.
60 skins	= 1 roll of parchment.

DRAWING PAPER.

	" "
Demy	20 × 15
Medium	22 × 17
Royal	24 × 19
Super-royal	27 × 19
Imperial	30 × 21
Elephant	27 × 23
Columbier	34 × 23
Atlas	33 × 26
Double elephant	40 × 26
Antiquarian	52 × 31
Emperor	72 × 48

UNITED STATES OF AMERICA.

Measures of Weight and Length are the same as the British, except that the cwt. is sometimes taken at 100 lbs., 20 of which go to the ton.

Dry Measure.

4 quarts .. .. .. = 1 gallon = 268·8025 cubic inches.
8 gallons .. .. .. = 1 bushel (Winchester).
1 Winchester bushel = ·96945 imperial bushel.

Liquid Measure.

2 pints = 1 quart = ·8331 imperial quart.
1 gallon = 4 quarts = ·8331 „ gallon.

Since 1866 the French metric system is legalised in the United States, the length of the mètre being fixed at 39·37 inches, the square mètre at 1550 square inches, the cubic mètre at 35·313657 cubic feet, and the standard gallon (liquid) at 231 cubic inches at maximum density. The standard lb. avoirdupois = weight of 27·7015 cubic inches of distilled water at maximum density, barometer at 30 inches.

FRENCH WEIGHTS AND MEASURES.

Lineal Measure.

Millimètre	.. .. =	0·0393704	English	inches.
Centimetre	.. .. =	0·3937043	„	„
Decimètre	.. .. =	3·937043	„	„
Mètre (62° F.)	.. =	39·370432	„	„
		3·280869	„	feet.
		1·093623	„	yards.
Kilomètre	.. .. =	1093·6231	„	„
Myriamètre	.. .. =	6·21377	„	miles.

Superficial Measure.

		métre.		Eng. sq. ft.		Eng. perches.
Centiare	=	1	=	10·7641	=	0·03953
Deciare	=	10	=	107·641	=	0·39534
Are	=	100	=	1076·4104	=	0·09884 rood.
Hectare	=	10000	=	107641·0356	=	2·47109 acres.

Note.—The above equivalent of the mètre is that determined by Captain Clarke in 1866 for the Ordnance Survey of Great Britain, and adopted by the Coast Survey of the United States of America, whereas the present legal, though erroneous value in England, is that determined by Captain Kater in 1818, viz. 39·37079 at 62° Fahr.

Solid Measure.

		mètre		
Stere ..	=	1	=	35·315617 English cubic feet.
Decastere	=	10	=	13·079858 „ „ yards.
Hectastere	=	100	=	130·798582 „ „ „
Kilostere	=	1000	=	1307·985823 „ „ „
Myriastere	=	10000	=	13079·858236 „ „ „

Weights.

Gram..	=	15·43235 grains avoirdupois.
Dekagram ..	=	·02204 lb.
Kilogram ..	=	2·20462 „
Millier	=	0·98421 ton. (= weight of a cub. mètre of water at 39·1° Fahr.)

Liquid Measure.

Litre	=	61·025 English cubic inches.
Dekalitre	=	610·254 „ „
Hectolitre	=	6102·5387 „ „
Kilolitre	=	61025·3866 „ „
1 Litre	=	0·2202 imperial gallon.
1 Hectolitre.. ..	=	2·7512 English bushels.

To reduce cubic mètres into English rods cube, divide by 8·664.

To reduce kilogs. per square millimètre to lbs. per square inch, multiply by 1422·30892.

A kilog. per sq. mètre = ·205 lbs. per sq. foot.

Millimètres to English Inches.

(Ordnance Survey Standard.)

Mill.	Inches.	Mill.	Inches.	Mill.	Inches.	Mill	Inches.
1	·03937	26	1·02363	51	2·00789	76	2·99215
2	·07874	27	1·06300	52	2·04726	77	3·03152
3	·11811	28	1·10237	53	2·08663	78	3·07089
4	·15748	29	1·14174	54	2·12600	79	3·11026
5	·19685	30	1·18111	55	2·16537	80	3·14962
6	·23622	31	1·22048	56	2·20474	81	3·18900
7	·27559	32	1·25985	57	2·24411	82	3·22838
8	·31496	33	1·29922	58	2·28349	83	3·26775
9	·35433	34	1·33859	59	2·32286	84	3·30712
10	·39370	35	1·37797	60	2·36223	85	3·34649
11	·43307	36	1·41734	61	2·40160	86	3·38586
12	·47245	37	1·45671	62	2·44097	87	3·42523
13	·51182	38	1·49608	63	2·48034	88	3·46460
14	·55119	39	1·53545	64	2·51971	89	3·50397
15	·59056	40	1·57482	65	2·55908	90	3·54334
16	·62993	41	1·61419	66	2·59845	91	3·58271
17	·66930	42	1·65356	67	2·63782	92	3·62208
18	·70867	43	1·69293	68	2·67719	93	3·66145
19	·74804	44	1·73230	69	2·71656	94	3·69082
20	·78741	45	1·77167	70	2·75593	95	3·74019
21	·82678	46	1·81104	71	2·79530	96	3·77956
22	·86615	47	1·85041	72	2·83467	97	3·81893
23	·90552	48	1·88978	73	2·87404	98	3·85830
24	·94489	49	1·92915	74	2·91341	99	3·89767
25	·98426	50	1·96852	75	2·95278	100	3·93704

Cubic Mètres into Cubic Yards.

(Ordnance Survey Standard.)

Cubic Mètres.	Cubic Yards.	Cubic Mètres.	Cubic Yards.	Cubic Mètres.	Cubic Yards.	Cubic Metres.	Cubic Yards.
1	1·308	26	34·008	51	66·707	76	99·407
2	2·616	27	35·316	52	68·015	77	100·715
3	3·924	28	36·624	53	69·323	78	102·023
4	5·232	29	37·932	54	70·631	79	103·331
5	6·540	30	39·240	55	71·939	80	104·639
6	7·848	31	40·548	56	73·247	81	105·947
7	9·156	32	41·856	57	74·555	82	107·255
8	10·464	33	43·164	58	75·863	83	108·563
9	11·772	34	44·472	59	77·171	84	109·971
10	13·080	35	45·780	60	78·479	85	111·179
11	14·388	36	47·087	61	79·787	86	112·487
12	15·696	37	48·495	62	81·095	87	113·795
13	17·104	38	49·703	63	82·403	88	115·103
14	18·312	39	51·011	64	83·671	89	116·411
15	19·620	40	52·319	65	85·019	90	117·719
16	20·928	41	53·627	66	86·327	91	119·027
17	22·236	42	54·935	67	87·635	92	120·335
18	23·544	43	56·243	68	89·943	93	121·613
19	24·852	44	57·551	69	90·251	94	122·951
20	26·160	45	58·859	70	91·559	95	124·259
21	27·468	46	60·167	71	92·867	96	125·567
22	28·776	47	61·475	72	94·275	97	126·875
23	30·084	48	62·783	73	95·483	98	128·183
24	31·392	49	64·091	74	96·791	99	129·491
25	32·700	50	65·399	75	98·099	100	130·799

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S.W.G.	Parts of an inch.	Millimètres.	S.W.G.	Parts of an inch.	Millimètres.
7/0	·500	12·700	23	·024	·610
6/0	·464	11·785	24	·022	·559
5/0	·432	10·973	25	·020	·508
4/0	·400	10·160	26	·018	·457
3/0	·372	9·449	27	·0164	·4166
2/0	·348	8·839	28	·0148	·3759
0	·324	8·229	29	·0136	·3454
1	·300	7·620	30	·0124	·3150
2	·276	7·010	31	·0116	·2946
3	·252	6·401	32	·0108	·2743
4	·232	5·893	33	·0100	·2540
5	·212	5·385	34	·0092	·2337
6	·192	4·877	35	·0084	·2134
7	·176	4·470	36	·0076	·1930
8	·160	4·064	37	·0068	·1727
9	·144	3·658	38	·0060	·1524
10	·128	3·251	39	·0052	·1321
11	·116	2·946	40	·0048	·1219
12	·104	2·642	41	·0044	·1118
13	·092	2·337	42	·0040	·1016
14	·080	2·032	43	·0036	·0914
15	·072	1·829	44	·0032	·0813
16	·064	1·626	45	·0028	·0711
17	·056	1·422	46	·0024	·0610
18	·048	1·219	47	·0020	·0508
19	·040	1·016	48	·0016	·0406
20	·036	·914	49	·0012	·0305
21	·032	·813	50	·0010	·0254
22	·028	·711			

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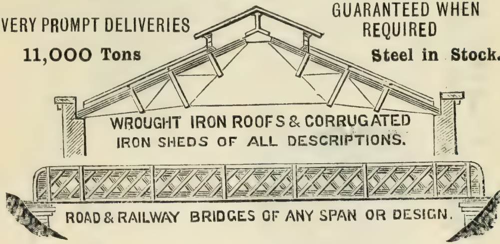

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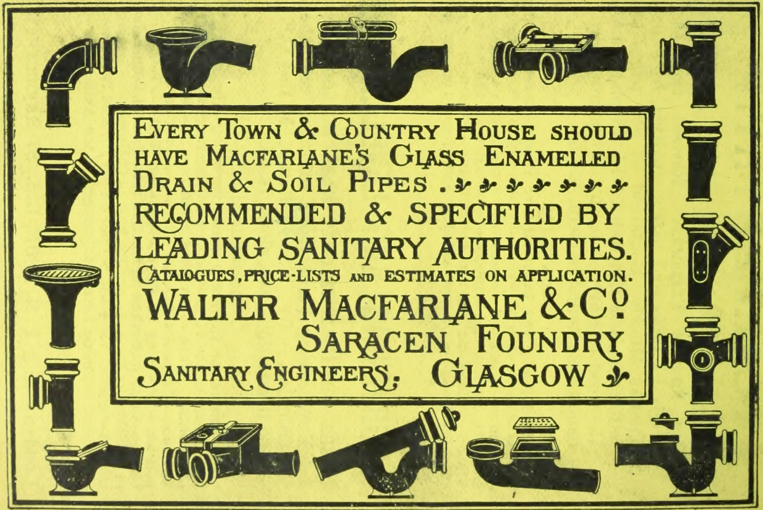
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